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Making prevention a priority

White Paper on Dental Carries Prevention and Management

**A summary of the current
evidence and the key issues
in controlling this preventable
disease**

Nigel Pitts & Domenick Zero

www.fdiworldental.org

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Preamble

The FDI-Colgate Caries Prevention Partnership (CPP) was formed in 2015. This new aspiring partnership aims at enhancing caries prevention through information, education and other activities targeting dental health professionals, patients and the public in general. It has the ambition to help shift the focus of dental practitioners from a Restorative approach to dental caries management to delivering Preventive Dental Medicine. The present White Paper aims to provide the foundation knowledge that is necessary to understand why change is important, and how it can be initiated and conducted.

Context

This partnership reflects FDI's longstanding involvement in caries prevention and management. Over the years, FDI has produced a range of documents advocating for a global paradigm shift from a so-called "curative", restorative approach to caries to an approach focused on prevention and disease control. These form the foundation of the present White Paper:

- Over a decade ago (2002)¹, FDI General Assembly approved a Policy Statement on "Minimal Intervention in the Management of Dental Caries" which recognized that "an operative ('surgical') approach should only be used when specifically indicated, e.g., when cavitation is such that the lesion cannot be arrested, or when there are aesthetic or functional requirements."
- In 2009, a glossary of terms in cariology was produced and disseminated in the frame of the Global Caries Initiative (GCI) led by FDI. This glossary helped the oral health community speak a common language.
- This work was accompanied by an FDI resolution on the "Principle of Caries Classification and Management Matrix"², adopted in 2011, which resolved that "The prevention of caries as an effective means to improve health is the guiding principle of the Caries Classification and Management Matrix".

- Further, in 2012, the FDI General Assembly adopted a Policy Statement on the "Classification of Caries Lesions of Tooth Surfaces and Caries Management Systems"³, which stated that "Scientists and clinicians now also recognize the need for a minimal intervention approach to surgical caries management, including the potential for arrest and remineralisation of early lesions" and recommended "the continued development and adoption of a caries lesion classification and a separate caries management system including risk assessment and prevention, that are able to describe and document the total caries (clinical) experience at a population and an individual level".
- In 2012, this substantial work culminated in a peer-reviewed article published in The Journal of the American Dental Association (JADA) "A new model for caries classification and management"⁴, produced under the leadership of Prof. Michael Glick (FDI Science Committee Chair at the time) and Prof. Nigel Pitts with input from the Science Committee.

Yet in spite of these sustained efforts to initiate a paradigm shift from restoration to prevention, uptake in daily clinical practice so far has been slow. The present White Paper, and its companion Advocacy Toolkit, are meant to provide National Dental Associations (NDAs) and dentists worldwide with the foundation knowledge and the necessary tools to drive change at both the level of clinical practice and at a policy level.

Process

On 21-22 September 2015, FDI hosted a two-day expert meeting (a summit and a workshop) on the theme of caries prevention, as part of its Annual World Dental Congress which took place in Bangkok, Thailand. The meeting was supported by the FDI-Colgate Caries Prevention Partnership. The meeting participants included FDI council members and experts from academic institutions, as well as practicing dentists from different countries. The purpose of this summit and workshop, which were led and facilitated by the authors of this White

Paper, Professors Nigel Pitts and Domenick Zero, was to identify the key issues of global/regional significance in caries prevention and management and suggest possible solutions that FDI member associations can adopt and/or adapt to their own circumstances and country contexts. The outline

of the present White Paper was also discussed in order to identify priority areas and to ensure the relevance of the issues discussed to FDI work and their alignment with FDI's vision and mission. The present White Paper therefore echoes discussions held during these meetings.

Executive summary

This White Paper sets out to provide an authoritative summary of both the current evidence and the key issues in dental caries prevention and management.

The authors view it as the dental profession's ethical responsibility to deliver caries care in the best interest of the patient by using the best available evidence to achieve and maintain oral health. With its clear clinical focus, this White Paper aims to equip dentists and other oral health workers as well as leaders in NDAs with the knowledge and tools that are necessary to adopt an evidence-based, contemporary approach to dental caries prevention and management.

In an introductory Section, this White Paper looks at the evolution of caries treatment approaches and, because dental caries does not sit in isolation, looks into comorbidities and common risk factors that are shared with other major non-communicable diseases (NCDs). It then moves on to presenting the most recent evidence on the aetiology, pathogenesis, classification, measurement and epidemiology of dental caries (Sections 2 & 3). Although different caries classification systems are available and referenced, this White Paper focuses on the ICDAS/ ICCMS™ system because it is considered to be the most comprehensive evidence-based system that has been developed to date.

In further Sections, this White Paper focuses on caries detection and assessment (Section 4) in a clinical context and sheds light on the importance of risk assessment in order to ensure a patient-centred approach (Section 5). With the aim of helping to identify high-risk patients in need of intensive preventive intervention before caries presents clinically, it then moves on to presenting evidence of effective and cost-effective primary (Section 6) and secondary prevention actions (Section 7) in a clinical context.

Building on previous Sections, this White Paper then presents the latest evidence on the importance of preserving tooth tissue (Section 8), and of minimum invasive interventions, to avoid the negative consequences of repeat restorative dentistry on pulp health and tooth fracture, and the potential negative impact of restorative materials.

In a further Section, the core elements of evidence-based clinical caries management are presented (Section 9). These involve: 1) determining caries risk, 2) detecting lesion severity and assessing lesion activity, 3) deciding personalised care plans at patient and tooth level, and 4) doing (performing) the right intervention, at the right time, to maintain tissue and health as well as schedule risk-based reassessment and review. This Section also includes a presentation of the ICCMS™ system as a case study.

In a final four Sections, this White Paper moves away from its clinical focus to widen its horizon by outlining a few overall challenges which represent both opportunities and threats on the journey that leads us from a restorative to a preventive approach. A first of these looks into remuneration for appropriate dental caries prevention and management (Section 10), outlining the urgent need to avoid perverse incentives which encourage dentists to drill and fill rather than prevent, and to move towards more outcome-based remuneration models. Section 11 looks into the evolving role of the dental team and other health professionals, with a specific focus on collaborative practices. It then focuses on the need to support change whenever and wherever it is required, locally, nationally and globally, towards individual practitioners, groups or entire health systems; and looks into a series of barriers to overcome (Section 12). It finally sheds light on the need to collect robust data to be able to assess outcomes and progress, and explores a few possible themes and pathways to collect and share such data (Section 13).

Space constraints preclude a full consideration of all the issues in this complex and developing field, but references will lead readers to further, more detailed, considerations.

Finally, in Section 14, this White Paper concludes with a call to action which outlines possible action pathways towards an up-to-date, evidence-based, tooth-preserving caries prevention and management practice. Actions listed cover many different fields. Some can be implemented by the dental profession itself, some pertain to education and can be discussed with dental schools, deans etc. and

others relate to policy and need to be brought to the attention of health authorities. Yet dental community leaders have a role to play in driving each of these actions forward.

Call to action - Key Points

Prevention

Because prevention is key, full support for caries prevention efforts at both the individual and population levels must be secured. With regard to **primary prevention**, targeted strategies need to be put in place to address different stakeholder groups (the lay public, dental practitioners, policy makers). Opportunities arising from the common risk factor approach to link caries prevention with hygiene and the control of obesity and diabetes must also be seized. With regard to **secondary prevention**, prompt and efficacious application of preventive care for lesions upon detection and assessment provides a very significant opportunity to stop lesions from ever progressing to the stage at which surgical intervention is required and must therefore be fully supported.

Clinical practice

A shift in clinical practice is needed to drive a change in the management of caries to detect them at an early (non-cavitated) stage. Within clinical practice, there is therefore a need to support dentists when moving towards an up-to-date, evidence-based, tooth preserving preventive caries management system and in working effectively with a wider range of partners in health. In addition, investments in technology developments in the areas of both lesion detection and activity assessment as well as risk assessment are urgently needed to help dentists, and the dental team.

Education

A redefinition of cariology curricula needs to be supported and promoted to ensure that they are up-to-date, evidence-based and delivered at both the undergraduate and continuing education levels.

Integration

Work towards a stronger integration of oral health within general health and health policy needs to

be promoted and supported: oral health should be seen as part of general health. Within dentistry, key “disciplines” such as nutrition, education and behaviour change, cariology and (dental) public health need to be aligned. Outside dentistry, the dental profession needs to advocate that “good oral health should be everybody’s business” and seek to join suitable actions from other external stakeholders, including other health professions.

Financing mechanisms

We call on NDAs to participate in the re-thinking of remuneration mechanisms for caries prevention and management, in order to ensure that remuneration is considered as an important element and that it incentivizes preventive, evidence-based tooth preserving caries management, in the best interest of the patient.

Evaluation and data

Finally, we call for data-driven, evidence-based caries prevention and management, which necessitates improving the quality of the data which is collected, and setting disease detection thresholds to allow prevention needs and successes to be assessed and monitored. It is therefore crucial to ensure that the four types of caries outcome measures defined in this White Paper (health maintenance, disease control, patient-centred quality and wider impacts of using a caries management system) continue to be developed and refined in ways that are appropriate locally, nationally and globally. Furthermore, it is important that the information technology (IT) support required to capture this information as efficiently as possible is developed locally, nationally and globally in parallel.

In conclusion, although evidence on adequate dental caries prevention and management has accumulated in the recent past, translation into practice has been slow so far. Now is the time to accelerate the move from restoration to prevention and minimal intervention, not least because, in addition to the purely clinical evidence presented throughout these Sections, the implementation phase of the Minamata Convention on Mercury, which foresees the phase down of amalgam, necessitates a stronger focus on prevention and a highly disciplined care strategy to preserve tooth structure and restore only when necessary.

Section 1 Introduction: evolution of caries treatment approaches and comorbidity with systemic health problems

This White Paper sets out to provide an authoritative summary of both the current evidence and the key issues in dental caries prevention and management; that is in controlling this preventable but almost ubiquitous disease of tooth decay⁵. Space constraints preclude a full consideration of all the issues in this complex and developing field, but references will lead readers to further, more detailed, considerations.

Many overlapping considerations are covered in the Sections that follow which discuss the elements that need to be addressed if we are to make significant progress in delivering more effective prevention and management of dental caries. It is, however, important to appreciate that a unifying theme and responsibility of the dentist in this area concerns ethics and professionalism. It is the ethical responsibility of the dental profession to deliver caries care in the best interest of the patient by using the best available evidence to achieve and maintain oral health.

Caries treatment approaches have evolved over the extended timeframe that the profession and practice of dentistry has developed across the world. There are inevitable country and regional variations in the evolution of care, but generally three phases have been described⁶. These are the: 1) extractive, 2) restorative, and 3) preventive phases of caries management. As would be expected, countries have progressed through these phases at variable rates over recent decades.

The extractive phase of caries control:

This strategy sought (and in some cases, where resources and the dental workforce is limited, still seeks) to use tooth extraction as the first line of treatment to stop pain and remove the threat of infection spreading from the consequences of caries which has progressed to involve the dental pulp and compromise its vitality. Extracting the offending tooth

was seen as good and appropriate practice when the alternative was continuing pain and the risk of sepsis and infection spreading to involve the oro-facial region and beyond⁷.

Shifts from the extractive to restorative phase:

The development of the air turbine dental hand piece dramatically increased the rate of cutting of tooth structure that could be achieved and, therefore, the dentists' ability to restore many teeth economically in a reasonable time frame. Across the developed and large parts of the developing world, this technology changed the way in which dental care could be delivered. There was a push to make tooth cutting and restoring multiple teeth ever more efficient. Dentists, dental manufacturers and health systems responded to this pressure. The development of "four-handed" and then "six-handed" dentistry were markers of this increasing restorative and technical focus. This approach was a step forward at the time and saved many teeth which would otherwise have been extracted and has been followed in good faith by generations of dentists.

These developments became intertwined with remuneration and compensation systems. In many countries incentives for efficiency have gradually become perverse incentives, where the dentist is only paid if he or she provides surgical intervention for caries and is not paid appropriately for detection, assessment, diagnosis and preventive care (this issue is discussed more fully in a later Section). Restorative-only treatment of caries was perceived by the profession and the public as "a good thing" and "modern"; however, the reassessment of this strategy is now overdue.

Increasing concerns have been voiced since the 1980s and 1990s about the long-term health and economic outcomes of an "outmoded" treatment philosophy using the restorative-only strategy^{1,3,5,8}. This was because of the stark contrast between

the largely technical and mechanistic approaches to tooth restoration, which ignored the control of causative factors on the one hand, and the emerging evidence from more biological approaches to dental caries aetiology and control on the other. Restorative care for caries is still a useful and needed treatment option, provided that tooth structure is preserved; but it is now seen as a “last resort” option rather than the “first choice” in every clinical situation^{1,5}.

Shifts from the restorative to preventive phase:

The so-called “repeat restorative cycle”^{5,9} is a process in which small fillings lead, over relatively modest periods of time, to larger fillings involving more surfaces, which in turn are replaced repeatedly, until the dental pulp becomes involved, which then requires the provision of endodontic treatment (or extractions), then crowns and then dentures (and more recently, also involves the provision of implants). The expectation among many in dentistry was that, as these dangers were recognized ever more widely, a more preventive strategy would be promoted and adopted. Frustratingly however, despite recognition of the problem¹, the need for a longer-term view to be taken when planning care for each patient and the importance of preserving tooth tissue^{1,3}, little has changed in many countries over decades and restorative-orientated systems of caries care and payment persist to this day.

This lack of change persists despite the widespread understanding gleaned from the decades of evidence of effectiveness of fluorides, sealants and other methods of sugar control and preventive care being translated into evidence based guidelines^{10,11}. In addition, there has been a shift in opinion amongst many in the dental profession moving towards a preventive philosophy where, at both population and individual patient levels, prevention is optimized and restoration is a last resort^{4,5,12–16}. There have been parallel initiatives to update undergraduate dental education in cariology in order to ensure that in the future the

profession is well equipped to deliver evidence-based caries care^{17–20}.

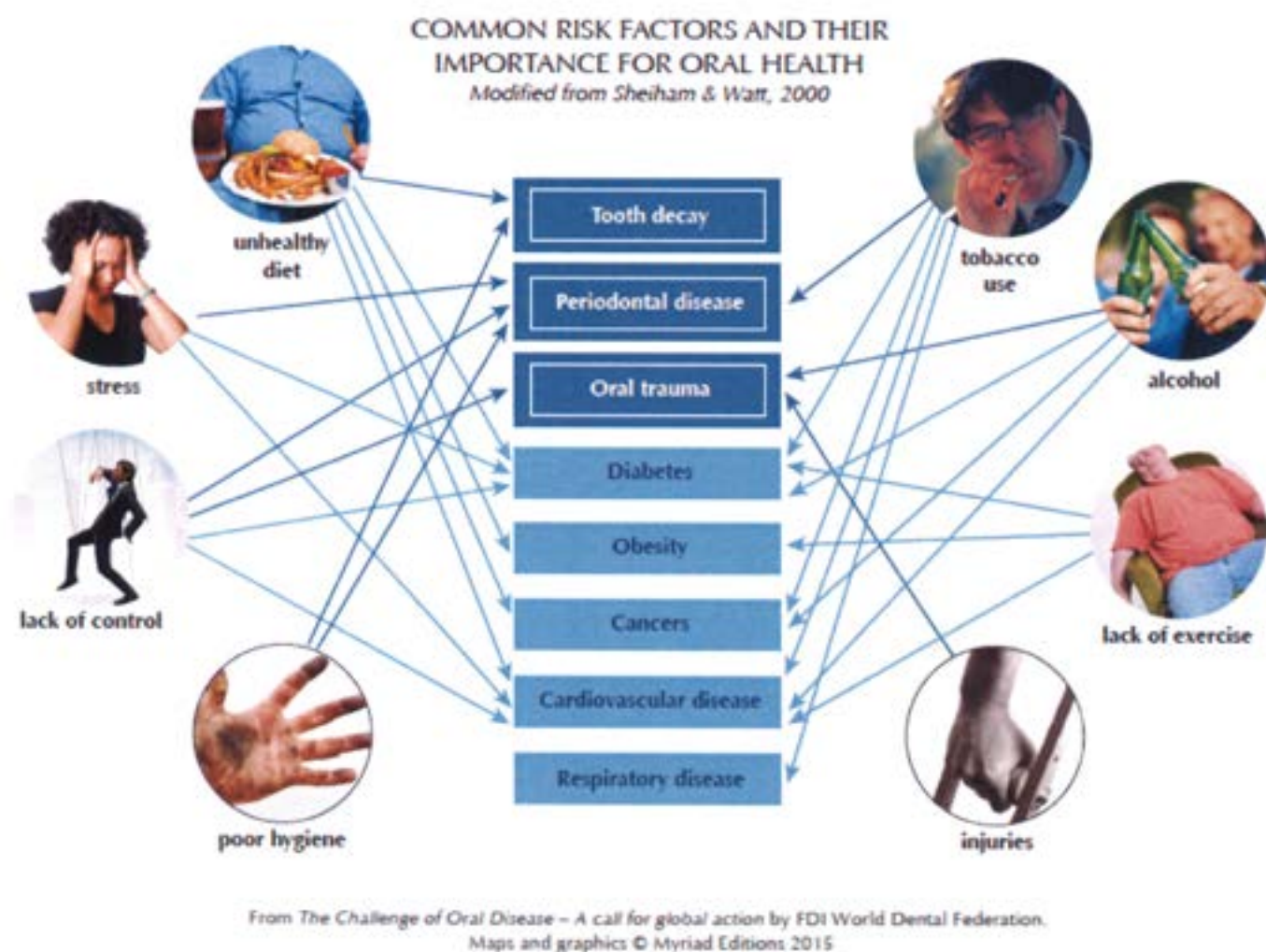
In many countries the transition from the restorative to the preventive phase has been slow, or delayed, or not there yet, *despite* the accumulating evidence and professional recommendations over decades. In some cases, new technology (implants) has even led to a step “back” towards a more extractive phase. Also, further perverse incentives have appeared in some remuneration models, which now pay better for extractions than for restorations and root canal treatments, let alone preventive interventions.

Subsequent Sections will show that caries should be managed with a patient-centred view across the entire life course. For some patients there are special caries challenges linked to vulnerable groups and the early, middle and late phases of life, which also have to be overcome. Evidence about the caries continuum - from initial-stage disease through moderate and extensive stages - and the trajectories of caries experience acquired throughout life, demonstrate that for the majority of those with caries in childhood, new caries will be likely to continue to develop into adulthood²¹. This means that risk-based caries prevention and management is needed across all age groups.

Comorbidity with systemic health problems

There is rightly a continuing examination of the many links between oral and systemic health and agreement that dentists should be at the heart of understanding these links and the evidence underpinning them⁸. The common risk factor approach to controlling NCDs, such as dental caries, is important. This means that the shared determinants of NCDs provide a range of opportunities to link caries prevention with preventive advice and interventions for other NCDs, such as obesity and diabetes. *Figure 1* illustrates the linkage between the common risk factors for NCDs and specifically the importance of diet and poor hygiene in dental caries prevention.

Figure 1 - Common risk factors and their importance for oral health



However, it must also be made clear that caution has to be emphasized with regard to over-claiming that mere associations are “causal” relationships.

Those who claim direct links between dental caries and systemic diseases are usually not supported by robust evidence.

Section 2 Aetiology and pathogenesis (what causes caries and what is the caries process?)

Introduction

Dental caries is a complex multifactorial disease involving interactions among the tooth structure, oral microbial biofilm formed on the tooth surface, dietary carbohydrates, mainly sugars and to a less extent starches, and salivary and genetic influences. The modern understanding of caries also includes consideration of how behavioural, social, and psychological factors are also involved in how the disease expresses in different individuals^{5,22,23}.

Biofilm bacteria metabolize sugars and produce acids that lowers the biofilm pH creating undersaturated conditions, which over time break down (demineralize) tooth enamel and dentin. The consequences of this process are the progressive destruction of the tooth's hard tissues, pain, abscess and possible tooth loss. Fluoride has altered the dose-response relationship between sugar consumption and caries experience by delaying when cavitation occurs and thus a higher cariogenic diet can be tolerated before caries occurs in many individuals²⁴. However, unacceptably high levels of caries in adults persist around the world even in countries with wide use of fluoride²⁵.

Role of host factors in caries aetiology

All teeth are susceptible to caries throughout an individual's lifetime starting with the crowns of the primary teeth and extending to the crowns and roots (following gingival recession) of the permanent teeth. The course of the disease process, and which teeth and tooth surfaces are affected, is dependent on several host factors, including location, morphology, composition, ultrastructure, and post-eruptive age of the tooth^{26,27}. The unique environmental conditions that exist of each tooth site explain the highly localized and complex nature of the caries process. The morphology of occlusal pits and fissures of molars create retentive area for biofilm formation and food retention rendering them to be most caries prone tooth surfaces in children. Teeth are

most susceptible to caries when they first erupt into the mouth and the solubility of teeth is known to decrease with increased post-eruptive age²⁶. The surface of teeth is covered by an organic film referred to as the acquire enamel pellicle composed mainly of salivary glycoproteins and proteins, which serves as the conditioning film and binding site for early bacterial colonizers involved in dental biofilm formation, but also can act as a physical barrier which decreases diffusion of biofilm acids^{28,29}.

Salivary factors involve salivary flow rate, buffer capacity, the proximity of teeth to salivary gland orifices, and salivary film thickness and velocity at specific tooth sites²⁶. Salivary flow rate is the main factor affecting the clearance pattern of cariogenic foods and beverages. Saliva also plays an important role in modifying biofilm pH³⁰. In the absence of normal salivary flow, the pH stays at a low level for an extended period of time after exposure to dietary sugars. Therefore, saliva is responsible for the recovery of biofilm pH back towards neutrality. Stimulated saliva, because of its higher flow rate (increased volume) and enhanced buffering capacity (bicarbonate buffering system), dilutes and neutralizes biofilm acids; however, this effect is mostly limited to the superficial layer of the biofilm.

The role of dental biofilm in caries aetiology

While dental biofilm formation is an essential step for caries formation, the presence of a biofilm on a tooth surface is not in and of itself an indication that disease is present. Views on the role of specific organisms, mainly *Streptococcus mutans*, in caries causation have changed over the last 25 years, and it is now recognized that many biofilm microorganisms have acid producing and acid tolerating properties including species from the genera *Veillonella*, *Lactobacillus*, *Bifidobacterium*, and *Propionibacterium*, low-pH non mutans streptococci, *Actinomyces* spp., and *Atopobium* spp²⁸. The focus is now on the biofilm

as a community of endogenous microorganisms and how ecological conditions, mainly determined by frequent consumption of dietary sugars and low saliva flow, can shift the biofilm from a state conducive to health to a caries-inducing state^{29,31,32}. Dietary sugars are readily metabolized by biofilm microorganisms to produce organic acids (mainly lactic acid), which lowers the pH of the biofilm. Bacteria are also capable of base formation when nitrogen-containing substrates (e.g., peptides, proteins) are available³³, and certain plaque bacteria (e.g., *Veillonella*) actually consume lactic acid as an energy source³⁴. Base formation and acid consumption can counteract the pH-lowering effect of acid production and may assist in a pH rise after dietary substrate has been depleted from plaque and acid production is low³³.

Dental biofilms are not pathogenic when transient lowering of the biofilm pH does not result in progressive net mineral loss. It is only with frequent and prolonged acidification of dental biofilm that biofilm microorganisms become pathogenic. This ecological pressure from biofilm acidification leads to progressive adaptation of the endogenous microorganisms to an acid environment which favours more acid tolerant (aciduric) bacteria and increased acid producing potential^{29,31,32}. This drives the biofilm pH down even further resulting in greater mineral loss and thus caries progression.

The role of diet in caries aetiology

While some authors have emphasized the importance of the dental biofilm²³ and others dietary sugars^{25,35}, both are essential primary aetiological factors driving caries expression, and one cannot cause caries in the absence of the other. The main direct impact of the diet is mediated through its effect on the pH of the dental biofilm. Diets high in fermentable carbohydrates (mainly sugars) favour a low biofilm pH, while diets high in proteins and fats favour a more neutral biofilm pH. High-protein diets increase the urea concentration of saliva which can be converted by ureolytic bacteria to ammonia; this raises the biofilm pH and is associated with decreased caries risk³⁶. Dietary factors can have an indirect effect by modifying the composition and metabolic activity of dental biofilm. As discussed previously, frequent and prolonged lowering of

biofilm pH as a result of excessive consumption of dietary sugars favours the growth of the more acid-tolerant (aciduric) bacteria, such as *S. mutans* and lactobacilli, which are also highly acidogenic. Therefore, the frequent consumption of sugar-containing foods and beverages gives a selective advantage to these cariogenic bacteria, allowing them to increase in number at the expense of other acid-sensitive biofilm bacteria that are less pathogenic. Diet can also have an indirect effect on biofilm pH by modifying salivary flow and composition. Coarse diets stimulate salivary gland function, whereas a soft or liquid diet leads to atrophy of the salivary glands and diminished salivary gland function³⁷.

Other dietary considerations are the type of carbohydrate, retentiveness of the food, the presence of protective factors in foods (calcium, phosphate, and fluoride)³⁸. The longer a food containing fermentable carbohydrate is retained in the mouth, the longer there is substrate for acid formation and for this reason the retentive properties of food is considered an important factor its cariogenic potential³⁹. Complex carbohydrates (starches) are considered less cariogenic than the simple sugars (sucrose, glucose, fructose)^{25,38}, with sucrose being the most cariogenic because of its unique role in the production of extracellular glucans^{24,40}. Starches are not readily soluble in oral fluids and have a low diffusion rate into the dental biofilm. They also must be broken down to maltose by salivary amylase before biofilm bacteria can use them. Most starch is cleared from the mouth before it can be broken down. However, most all modern processed foods contain a combination of starch and sugar and can be highly cariogenic due to prolonged retention in the mouth⁴¹.

Sucrose represents the main source of sugar in the diet and has been implicated as an important determinant of dental caries^{24,40}. Epidemiological and experimental studies have shown a causal relationship between sucrose exposure and extracellular glucan synthesis, and caries experience⁴⁰. Similar to other simple sugars (glucose, fructose, maltose), sucrose is freely diffusible in dental plaque biofilm and readily metabolized by oral bacteria. However, sucrose has the unique property in that it is the

main dietary substrate involved in the synthesis of soluble and insoluble extracellular glucan by glucosyltransferases (GTFs) from *S. mutans*. There are several mechanisms to explain the role of extracellular glucans as the major caries-associated microbial virulence factor. There is evidence that their presence in plaque promotes bacterial adherence to the tooth surface and contributes to the structural integrity of dental biofilms⁴⁰. Studies using an in situ caries model have shown that the presence of insoluble glucan markedly enhanced demineralization potential of *S. mutans* test plaques^{26,42}. The effect has been attributed to an alteration of the diffusion properties of plaque, allowing deeper penetration of dietary carbohydrates²⁶.

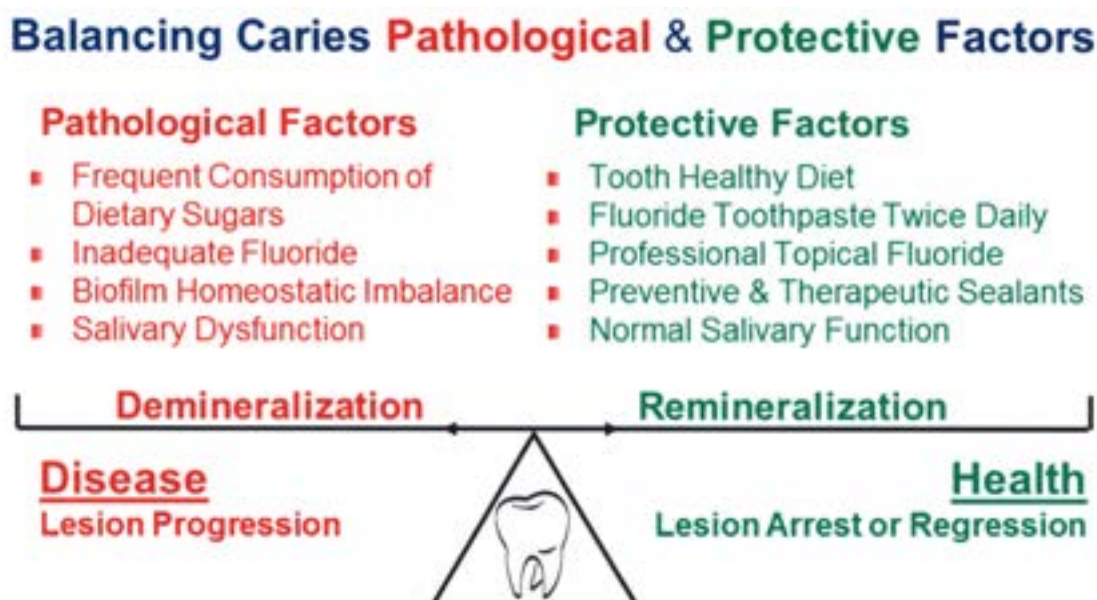
A recent systematic review has concluded that caries is much less likely to occur in the absence of dietary free sugar intake above a threshold of 5% of energy intake³⁵. Although the strength of this relationship has been modified with the introduction of fluoride, from a causative basis, dietary sugars still remains the main driver of caries^{24,25}.

Caries process

Our basic understanding of the caries process dates back over 125 years to W.D. Miller's (1890) Chemoparasitic Theory and to a large extent we are still managing dental caries using turn of the last century surgical approaches intended to remove the demineralized tissue and halt the disease process. Today dental caries is understood as a dynamic process involving cycles of mineral loss (demineralization) and mineral gain (remineralization)^{26,43,44}. Several protective and pathological factors are involved that can shift the balance towards health or disease (see Figure 2).

The tooth surface is in a healthy state of dynamic equilibrium with the local oral environment when demineralization and remineralization are in balance or favour remineralization. The caries process occurs under oral conditions that lead to more net demineralization than remineralization resulting in sustained net mineral loss. The demineralization phase starts with the formation of organic acids, mainly lactic acid, as an end product from sugar metabolism³². As acid builds up in the

Figure 2 Caries process involves shifts in the balance between pathogenic and protective factors



Modified from Pitts, 1983 & Featherstone, 1999

biofilm, the pH drops to the point where the mineral phase of tooth, hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$), begins to dissolve. This occurs when the conditions are sufficiently undersaturated with respect to tooth mineral, and there is an outward diffusion of dissolved mineral away from the tooth²⁶. The lower the pH, the greater the degree of undersaturation and the greater the rate of demineralization⁴⁵. Tooth enamel begins to demineralize in the 5 to 6 pH range with an average pH of 5.5 being generally accepted as the critical pH at which enamel dissolves. However, this cannot be considered a fixed value, because the critical pH varies depending mainly on the concentration of fluoride, calcium and phosphate ions, and solubility properties of the mineral at a specific tooth site⁴⁶. The critical pH is thought to be higher for dentin, around pH 6.

As the demineralization process proceeds, reaction products (dissolved mineral) build up at sites in intercrystalline spaces of enamel. This eventually raises the degree of saturation of the demineralization fluid to the point where it is now supersaturated with regard to the tooth mineral, stopping the demineralization process and favouring mineral reprecipitation. For this reason, the outward diffusion of mineral ions toward the surface is considered the rate determining factor for demineralization⁴⁷. The enamel surface receives the benefit from calcium and phosphate concentrations building up in the biofilm as well as reaction products diffusing from the subsurface enamel. These phenomena may explain, in part, why the rate of demineralization is greater for the subsurface enamel than for the surface enamel. As conditions change from undersaturation to supersaturation in the surface enamel, the acids diffusing from the biofilm do not react with crystals in the surface layer and continue deeper into the subsurface enamel, where conditions are undersaturated. Thus, demineralization and remineralization can be occurring in different locations of a lesion at the same time.

Under conditions when sugar metabolism is not taking place, the biofilm pH tends to be in the

neutral or basic range and the fluid phase of the biofilm is sufficiently saturated with calcium and phosphate ions so that redeposition of mineral (remineralization) is favoured. The presence of low levels of fluoride reduces the net mineral loss during acid challenge and greatly enhances the reprecipitation process which is considered the main mechanism of action for fluoride⁴⁸. Fluoride has a high affinity for the surface of the crystallites forming the enamel prisms. Once fluoride is associated with the enamel crystallites, they take on the solubility behaviour of fluorapatite, which has a lower solubility than hydroxyapatite. This effectively lowers the critical pH that enamel will demineralize to 4.5, thus reducing the caries susceptibility.

The very early (subclinical) stage of caries involves direct dissolution and softening of the enamel surface with an opening up of the structural features of the surface as pathways for diffusion. As demineralization progresses deeper into the enamel, the rate of mineral loss becomes greater in the subsurface than at the surface, resulting in what is commonly referred to as a white spot (non-cavitated) lesion. The enamel surface remains relatively intact while caries progresses in the deeper subsurface zone. At this very early subclinical stage, the demineralization and remineralization process may remain at this stage for weeks, months or years and may never advance to be clinically detectable. Fluoride can shift the balance in favour of arresting or reversing this early stage of the caries process as well as slowing down the progression of more advanced lesions. If the imbalance between mineral loss and mineral gain continues, this can lead to the early clinical signs of disease (white spot) and ultimately the more advanced signs (cavitation) become evident⁴⁹.

Action steps

This modern understanding of the caries process supports the shift in caries management to detecting caries at an early (non-cavitated) stage and risk assessment to determine appropriate preventive intervention and recall frequency.

Section 3 Classification and epidemiology

Caries classification

Overview

The classification of dental caries has been unusual, in that the system originally proposed by GV Black, and used almost universally worldwide for more than 100 years, evolved from a method of classifying carious cavities on exposed tooth surfaces for operative (surgical) procedures with materials available in the early 1900s, and not in characterizing the disease³. Black himself (who later researched caries in the enamel), would probably be horrified that his system has remained in unchanged use for so long, despite the increase in knowledge about the disease process, the importance of the initial stages of caries, and the radical shifts in dental diagnosis and materials technology that have taken place since 1908.

Outside of operative dentistry, in the research and epidemiology domains, details of the classification of the disease into various stages of severity, including, at the very least, caries visually: a) in enamel, b) in dentine and c) into the pulp have been widely known and used^{50,51}. The importance of understanding the diagnostic threshold or level used to classify both diseased and sound surfaces of teeth, particularly in lower caries prevalence groups, was illustrated with data from Hong Kong almost 30 years ago⁵².

It is useful to think of caries using the “Iceberg” metaphor to explain the different stages of disease severity, which has been used widely, since 1994, to explain the stages of caries in Public Health⁵³, Education and Research groups in Dentistry, as well as in communicating about the disease to Physicians⁵ (Figure 3).

Figure 3 The iceberg of dental caries

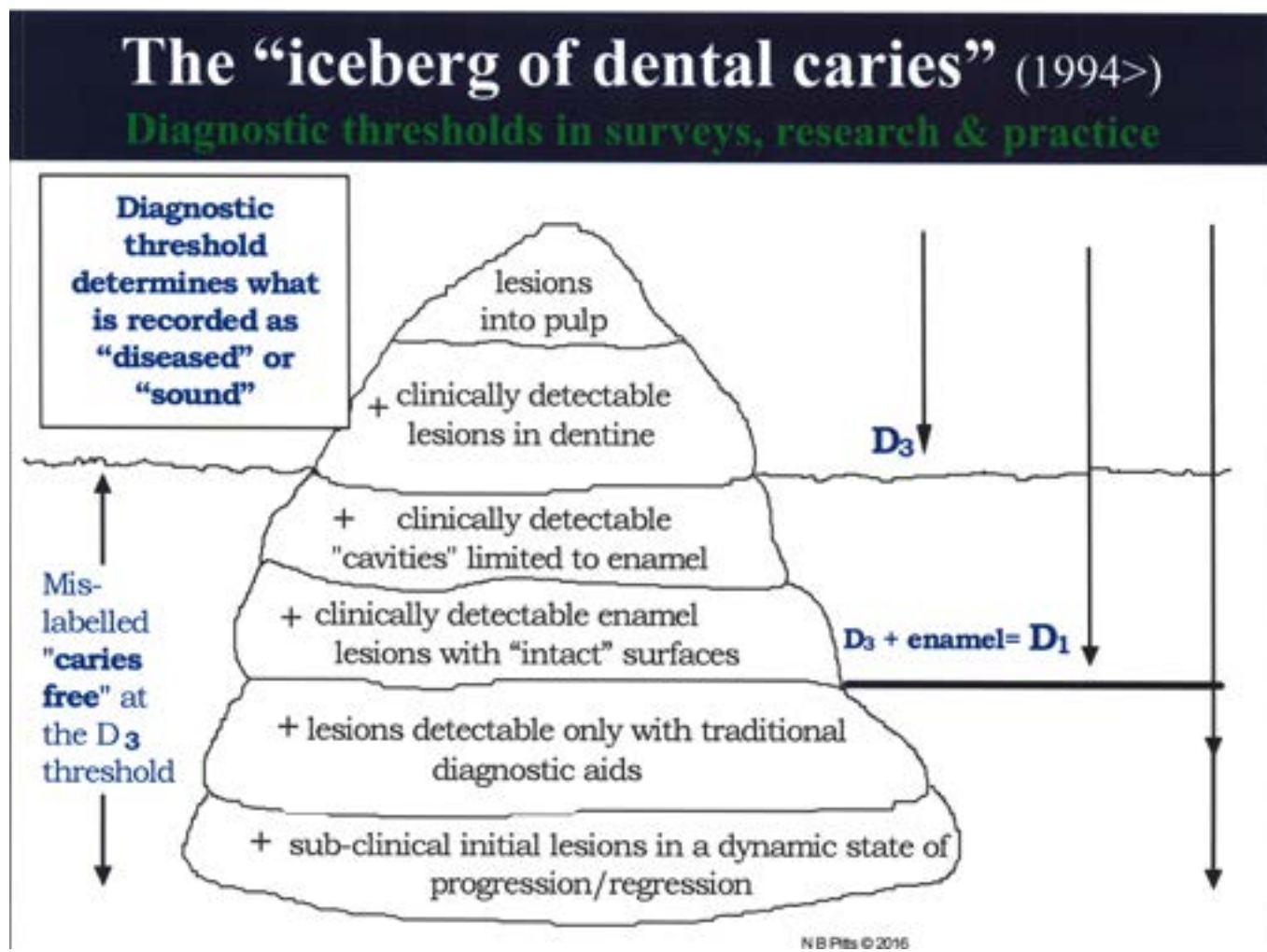


Figure 3 provides an overview of the iceberg with diagnostic thresholds:

- When using what was, for decades, termed the D₃ caries threshold, large lesions with open cavities extending **into the dental pulp** together with more limited open cavities **into the dentine** are visible “above the waterline”⁵².
- If caries is measured at this threshold, then only these two stages of lesion severity are counted, and all the lesions below the hypothetical water line are called “sound”, along with truly sound tooth surfaces.
- If, however, the classification used also recognizes clinically detectable **cavities in enamel** (where the enamel surface is broken but dentine is not visually involved) and clinically detectable lesions in enamel with macroscopically intact surfaces (the so-called “White-spot” lesions), then many more lesions will now properly be regarded as caries and the estimates of caries present in an individual or a population will increase.
- This is using what is known as the D₁ threshold, which is the D₃ threshold value with enamel lesions added.
- If, however we use a threshold which includes the additional lesions which a dentist would find in a surgery/clinic setting by using bitewing radiographs (or other lesion detection aids), then once again the number of lesions identified as caries will increase.
- Even in these cases, however, we know that at the microscopic and ultrastructural level (sub-clinical) there will still be further initial-stage lesions in a dynamic state of de- and re-mineralization⁵, which cannot be detected clinically, but will be present within the tooth.

In these circumstances, understanding that all of the above stages are part of the caries continuum, it is inappropriate to label only those lesions shown here above the water as “caries” and **all** the other stages being classified as “caries-free”, in error. Modern terminology should, for the D₃ threshold, refer to individuals having either: “obvious decay” or “No obvious decay”⁵. This type of classification

and presentation allows a link to be established between lesion severity and the management option most appropriate for each stage lesion detected¹² in terms of Preventive Care Advised PCA or Operative Care Advised OCA. The provision of this type of preventive PCA or “Non-Operative” Care has been recommended and referred to a “New paradigm” for decades⁵⁴.

Classification systems

The majority of caries classification systems have focused on one application or user community. Black’s classification was designed to be used in clinical practice, the Decay, Missing, Filled (DMF) Index was designed as a caries count to be used in epidemiological studies. Remarkably, the International Caries Detection and Classification System (ICDAS) set out from the start to be applied across the four domains of Epidemiology, Practice, Research and Education^{55,56} and to have a “wardrobe” of choices at different levels of complexity for different user needs, which evolved over many years from meetings in the US, Europe and Latin America to get to a Bogota Consensus grid in 2008⁵⁷ and simpler formats available on the ICDAS website⁵⁸.

The need for the ICDAS approach arose from the International Consensus Workshop on Caries Clinical Trials (ICW-CCT) held in 2002⁵⁹ in which stakeholders from across academia, industry, professional organizations (including FDI and International Association for Dental Research (IADR)) came together to assess where the evidence led in caries. The harmonized ICDAS system brings together the best aspects of a range of earlier individual named systems and came into being following the revelation from a review presented at the ICW-CCT meeting that there were no less than 29 unique criteria systems for classifying caries in different ways, with substantial variability around the examination conditions used and the extent of the disease process measured⁶⁰. These fundamental differences compromise the ability to compare the results of different clinical studies, to interpret epidemiology and to transfer research evidence into daily practice⁵⁵.

In 2012, FDI Science Committee published an Editorial on A new model for caries classification

and Management – the [FDI World Dental Federation Caries Matrix](#)⁴. This paper contains an excellent review of all the key caries classification systems available at that time. The lead systems (and the area they covered) which were selected for review were:

- Black’s classification (clinical practice - operative dentistry)
- World Health Organization’s (WHO) “Basic Methods” for oral health surveys using the DMF index at the D₃ level; note that an “Advanced Methods” system from WHO was in use in the 1970s and used DMF at the D₁ level, but WHO did not continue to maintain this (epidemiology)
- ICDAS system (epidemiology, clinical practice – preventive & operative, research and education)
- A proposed but not then detailed American Dental Association Caries Classification System (clinical practice)
- Mount-Hume classification system (clinical practice- operative)
- Site/Stage (Si/STA) Classification System (clinical practice - operative)
- Caries Assessment Spectrum and Treatment System (CAST) (epidemiology)

The article presents a review of the strengths, potential gaps in and deficiencies of these seven selected systems and presented FDI Caries Matrix as a framework (not a new system), which integrated existing systems so that It could be used by clinicians, researchers, educators and public health workers and decision makers⁴. It points out that the framework used the terminology from the “international glossary⁶¹ adopted by FDI in 2010” and that “The ICDAS Foundation, building on earlier work, uses a similar layered approach across key domains for its International Caries Classification and Management System (ICCMS™)¹⁵.”

The important commonality shared by both the ICCMS™ caries wardrobe and the FDI Caries Matrix, is that there are three levels of classification, that can be chosen according to purpose and preference, which include a:

- 1) Simple “No obvious decay” or “obvious decay” call at the cavitated caries into dentine D₃ threshold (WHO Basic Methods, ICCMS™ Basic Reporting Tool)
- 2) Second level which corresponds to the D₁ threshold including enamel caries with a limited number of stages of caries severity (ICDAS collapsed/merged codes format, ADA Caries Classification⁶²)
- 3) Comprehensive staging of caries severity across the caries continuum using the full 6-stages of caries ICDAS/ICCMS™ codes

Key considerations are that these frameworks: a) allow users to compare results in a valid manner with clarity as to the detection thresholds used for specific purposes; b) allow users to collect data in such a way that the results can be expressed at several of these levels, according to need and choice; and c) where appropriate, use the PUFA index, which records in extensive caries situations: pulpal involvement, ulcerations, fistulas and abscesses.

Since this overview paper was published there have been further developments coordinated by the ICDAS Foundation, which have followed the recommendations of the 2012 FDI Policy Statement in this area, such as in continuing the “development and adoption of a caries lesion classification system” (which is the ICDAS element) “...and a separate caries management system” (which is the ICCMS™ element referred to above) “including risk assessment and prevention that are able to describe and document the total caries experience at a population and an individual level”³. The implementation of ICCMS™ is also, since 2013, being addressed by a Global Collaboratory for Caries Management (GCCM) administered by the ICDAS Foundation. This seeks to address FDI recommendations to use such systems “as the basis for communicating and educating patients, health professions and governments about caries, its prevention, control and management”³. There have also been some other parallel developments on the epidemiology side of caries classification with the CAST Index – see the Section below.

Caries epidemiology

Dental caries epidemiology is important and should ideally provide all stakeholders (including: governments, public health officers, health professions and their associations, the public and patients) with timely, accurate and understandable indications for key age groups across the life-course of the: amount of disease present (prevalence); rate of progress of disease (incidence); and disease trends over time in order to help planning. In addition, information on variations in disease levels between and within countries, including estimates and trends in inequalities and health gradients are now actively sought by many. Although dental caries has been repeatedly said to be the most prevalent disease on the planet⁶³, unfortunately we do NOT currently enjoy accurate, up to date, clinically meaningful information meeting the specification outlined above at the global level, or often, even at local levels.

This mis-match between the scale of the disease on a global basis and the societal burden of caries on the one hand and the lack of interest in maintain caries epidemiology on the other is something of a paradox. When oral health was added to the

on-going Global Burden of Disease Study⁶⁴, it was found that oral diseases remain highly prevalent, affecting some 3.9 billion people. Untreated caries in permanent teeth was the most prevalent condition evaluated across the entire study of all medical conditions, with a global prevalence of 35% for all ages combined. Untreated caries in children ranked the 10th most prevalent condition and these estimates increased between 1990 and 2010.

Despite the disease being so common, and not just in children, but continuing along defined life-long trajectories into adulthood²¹, and despite the scale of the challenge to tackle inequalities in the caries arena¹⁸, it is frequently afforded scant priority by public health organizations in many countries, and also by the WHO. If we are to make significant progress with caries prevention and management, the profile of the disease and its consequences need to be raised. If we are to understand if progress is being made in the fight against caries, we need more reliable and meaningful data to be recorded and made available at appropriate time intervals meeting the specification given earlier. The scale of caries inequalities is also profound and concerning.

Figure 4 Global Epidemiology of late-stage caries – limited current information on dentine caries

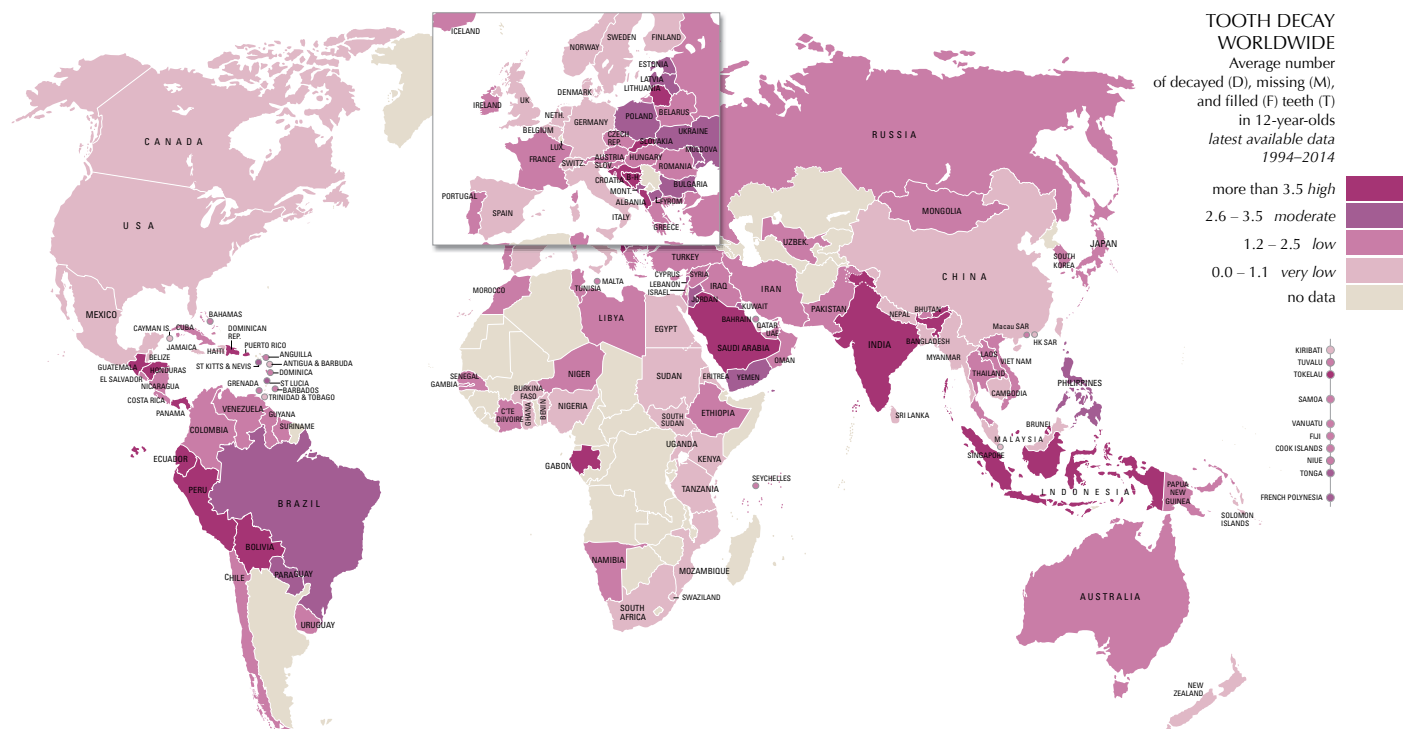


Figure 4 shows a comprehensive, recent and invaluable attempt to assemble a world view of dental caries in 12-year-old children; it is from the [FDI Atlas](#)⁶⁵. Whilst this overview is very useful indeed given the current limitations on data to collect, it is disarming to realise that the:

- Data reported was collected between 1994 and 2014 (so Countries cannot be compared at the same time points)
- Threshold level used is the very simple “no obvious decay” or “obvious decay” call at the cavitated caries into dentine D₃ threshold, above the water-line in Figure 3 (which will be a very significant underestimate of the real prevalence of disease when moderate and initial stage caries is also considered)^{66,67}.
- Level of rigor used in sampling, training, calibrating and survey design as well as the representativeness of the data for the countries concerned varies enormously.

Recent work by a number of European Organizations coming together with work facilitated by European Chief Dental Officers has shown – by way of a global example – that when assessing

data and information from 43 European countries the “findings support the view that most of current national caries data for DMFT levels in 12-year-old children are not comparable across Europe”⁶⁸.

Against this overall picture of concern, there are positive efforts worldwide to improve our understanding of caries epidemiology, to improve methodologies and optimize them for epidemiological field use. In epidemiology the ICDAS modifications recommended in 2009 and comparisons with the WHO Basic Methods criteria⁶⁹ have been used in many countries⁷⁰ along with the simplified merged-codes option, while the Icelandic National Survey of Children⁶⁶ demonstrated the magnitude of the underestimation of conventional surveys when radiographic information is also available – as it would be in dental practice.

The Caries Assessment Spectrum and Treatment (CAST) epidemiological Index was described in 2011⁷¹; it combines elements of ICDAS II, PUFA and DMF Indices in a pragmatic way. This new Index has been developed further by assessing its reproducibility in clinical studies⁷² and by a study comparing its outcomes with WHO Basic Methods⁷³.

Call to action elements: the key elements that need to be addressed in these areas are listed in Section 14.

Section 4 Caries detection and assessment in a clinical context

The clinical context

The **detection** and **assessment** of caries lesions is the clinical foundation on which rational caries care planning and delivery is built. These are both essential steps in providing high-quality evidence-led caries care^{74,75}, but are steps which are often taken for granted or neglected. This is either by busy dentists - who regard their well-honed skills in this area as an almost programmed, “automatic” and basic part of their work, or also by those designing dental care systems and payment systems - who in many countries have focused on the surgical or technical aspects without paying sufficient attention to the impact of these steps on the quality and appropriateness of the care subsequently provided (and paid for).

This Section considers the clinical aspects of caries Classification, which as a subject has been discussed in depth in the previous Section. It deals with how disease severity is and should be “staged” and how caries activity is and should be assessed. Other Sections later deal with determining caries risk and deciding on what is the clinical management option to perform for each lesion.

Terminology

The terminology used when discussing the clinical classification (and management) of caries has been problematic as there have been different groups using the same words for very different meanings in science, education and practice and across different geographic regions. In the area of “caries diagnosis”, one of the key outcomes of the International Consensus Workshop on Caries Clinical Trials (ICW-CCT) held in 2002⁵⁹ was to agree an international consensus to differentiate between: **Lesion detection** (*an objective method of determining whether or not disease is present*); **Lesion assessment** (*which aims to characterize and monitor a lesion once it has been detected*); and **Caries diagnosis** (*a human professional summation of all available data*).

The challenge to agree definitions for other key terms in cariology was taken on by a small group who attended the Workshop and they subsequently worked with the ICDAS Committee and published an International Glossary of Key Terms as part of a Monograph in 2009⁶¹. This Glossary was then adopted by FDI as part of its Global Caries Initiative in 2010⁴ and was distributed widely to NDAs and stakeholders as a move towards achieving a common language for dental caries. A compatible list of definitions was included as an introductory article in Dental Clinics of North America book on Current Concepts in Cariology in 2010⁷⁶.

More recently another group has helpfully made some consensus recommendations on the terminology focused on caries removal techniques and the management steps in operative caries care⁷⁷. However, this works highlights the importance that these initiatives should be, wherever possible, compatible with each other, and that they should recognize earlier work in the field to ensure that such efforts do not confuse the user community. There has been a historical gap between many in dentistry working on the preventive control of caries and those tackling the evidence around the more advanced stages of the caries process, increasingly and importantly in a minimally invasive way. For the sake of patients (who don't recognize or understand such boundaries) these gaps should be closed and the collaborative activities integrated more closely to achieve a seamless fit between preventing new caries, non-operative control of lesions and tooth preserving operative care of lesions. Holistic patient care should be increasingly reflected by joined-up terminologies.

Caries measurement in a clinical context

As the clinical challenge faced by dentists and their teams in preventing and managing dental caries has become more complex, the ways in which they need to measure and assess caries has also changed,

even if education and practice have sometimes been slow to keep up in this key area.

Figure 5 shows in “cube” format the three aspects of modern caries measurement with a focus on the preventive or non-operative control of early and moderate stage lesions. This concept has been communicated and developed widely over the extended period since the ICW-CCT Workshop in 2002, to now span engagement in the research, practice and education domains^{18,78,79}. The three key aspects represented in the Figure are:

- *Detecting lesion extent*
- *Assessing lesion activity*
- *Monitoring lesion behaviour*

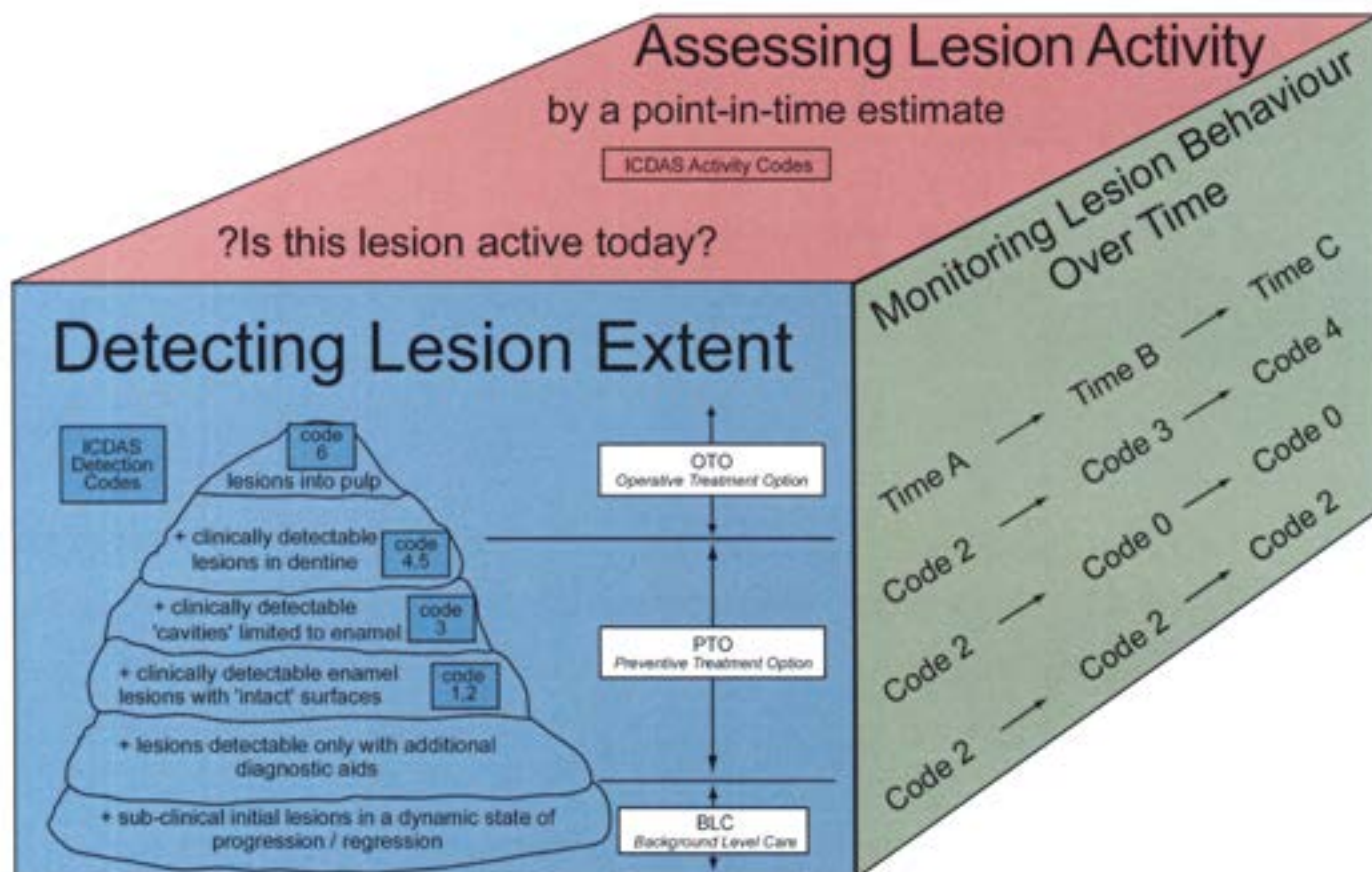
Detecting lesion extent

The discussion in the previous Section on detection thresholds and classification systems has covered

the essentials of detecting lesion extent, but the clinician also has to consider the need for assessing both care needs and outcomes in individual patients. This usually means using some sort of lesion detection aids to supplement clinical visual examinations which although the key element, has well understood limitations, particularly at approximal sites.

A contentious issue over decades has been the use of a sharp probe or explorer (sometimes with considerable force) as a “diagnostic aid” in pits and fissures. It has been known since the 1990s that there is no evidence to continue this practice as there is no diagnostic benefit, but there is a risk of iatrogenic harm, converting arrested initial lesions into damaged surfaces where caries will likely progress. Despite this evidence, change in many countries has been slow and many dentists still use this outdated method. The best method to assess caries visually is to inspect clean dry teeth

Figure 5 – Three facets of modern caries measurement



with sharp eyes but blunt probes (after Emeritus Professor Edwina Kidd).

Traditional methods in use as caries detection aids include bitewing radiographs, transillumination and elective temporary tooth separation⁸⁰ while there continue to be newer emerging alternatives that seek to give dentists the additional clinical information they require, but without the hazard of ionizing radiation⁸¹.

The front face of the cube in *Figure 5* uses the iceberg metaphor outlined in the last Section, but adds for reference the full ICDAS code set (1-6) and also indicates likely type of management options for differing lesion severities, separating background level preventive advice and care from preventive treatment options directed at individual lesions, to operative options where minimally invasive surgical intervention is required.

Assessing lesion activity

This is a vitally important and currently often neglected step in: a) understanding dental caries at the lesion level; b) assessing the need for any lesion-specific intervention; and c) assessing the success of any caries control intervention in converting an active progressing lesion into a controlled one. The essential challenge (summarized on the top face of the cube) is to differentiate between firstly a lesion which is **active** today and continuing to suffer net loss of mineral, with demineralization being out of balance with remineralization, as opposed to a lesion at a similar state of severity which has been “switched off” and become **inactive**, that is arrested or remineralized. The clinical and economic implications of making the correct lesion activity assessment are profound, yet for many dentists such an assessment is absent or perfunctory – with no information being recorded in the patient’s record.

Although the evidence to allow accurate, reliable caries activity assessment is not yet as robust as it is for lesion detection, we now have a wealth of

evidence from many years guiding us in making such clinical assessments and these systems should be used judiciously whilst we wait for better tools. Key steps along the development of this field have been summarized elsewhere^{82,83}. Comparison of the available clinical caries activity measurement systems in primary teeth of children has shown that the presence of mature dental plaque and tooth type are both important tooth-related factors for caries activity while anterior caries and age are variable related to the child⁸⁴.

Monitoring lesion behaviour

Over time this is becoming more important as the pattern and speed of progression of caries has changed in many groups of patients and the need to preserve sound tooth structure and practice minimally invasive dentistry¹ is appreciated more widely. It is important that accurate assessments are made and that lesion-specific records can be stored and re-viewed at later visits to plan appropriate care and assess outcomes.

It has been appreciated for some years that technology developments in the areas of both lesion detection and activity assessment are urgently needed to help dentists, the dental team and patients. Space for such methods has been reserved in the ICDAS Consensus grid since 2008⁵⁷, but although progress with devices to use in dental practice has been frustratingly slow, this remains a priority area in order to support dentists’ optimal assessment, re-assessment and minimally invasive clinical care.

Assessing more extensive lesions is important as the need for more conservative treatment planning is accepted and as changes in the outlook on management of oral health and dental disease have developed over decades for both dental professionals and the public...now is the time for these changes to be implemented in practice⁸⁵. Consensus on the methods and terms for clinicians to use is improving⁷⁷.

Call to action elements: the key elements that need to be addressed in these areas are listed in Section 14.

Section 5 Caries risk assessment

Introduction

More and more healthcare, including dentistry, is becoming personalized by focusing on a specific patient's needs to complement broader population-based strategies. Water fluoridation (if available) and routine use of fluoride toothpaste can provide caries preventive benefits for the majority of the population; however, many individuals who still are getting caries and/or at risk of developing caries in the future need more individualized caries management strategies. Risk assessment must be considered an essential component in the clinical decision-making process in dental practice to determine the appropriate level of patient care. With the advent of widespread use of fluoride, the prevalence, severity, and rate of caries progression have declined. Consequently, practitioners can adopt a more conservative approach and apply the principles of modern management of dental caries. These involve detecting and assessing caries lesions at an earlier stage, determining the patient's caries risk status, applying intervention strategies focused on preventing, arresting, and possibly reversing the carious process, and delaying restorative treatment until absolutely necessary⁸⁶. Caries risk assessment along with the early caries detection are the foundations of modern patient-centered personalized caries management.

Caries risk assessment

Caries risk assessment can play several important roles in the clinical management of dental caries: 1) helping dental professionals determine if additional diagnostic procedures are required; 2) identifying patients who need additional caries control measures; 3) in assessing the effectiveness of interventions to prevent caries; and 4) guiding clinicians in making treatment planning decisions and in scheduling the frequency of recall appointments⁸⁷. The main goal of caries risk assessment is to target the appropriate level of intervention - preventive care and/or treatment - for patients based on their caries risk status. For patients who are at low risk to future disease, no additional intervention is indicated. For patients

who are at moderate or high caries risk to future disease, additional preventive measures are indicated including patient education directed at improving their oral health behaviours (e.g., oral hygiene, dietary counselling), and increasing protective factors (e.g., fluoride exposure, dental sealants, salivary stimulation). As with all clinical care of dental patients, any intervention should be in the best interest of the patient and based on the best available scientific evidence.

Scientific reviews of the literature have found that the single best indicator of a patient developing caries in the future is previous caries experience^{88–91}. If there are clinical signs of active demineralization (caries active lesions) the patient should be considered as a risk for caries progression and both primary and secondary preventive measures put in place. One can assume that if there are active signs of disease that other teeth and tooth surfaces may be experiencing caries progression that is below the level of detection (subclinical) and can benefit from caries prevention measures⁸⁹. Ideally we would like to identify patients who are at risk before they develop caries and implement primary prevention strategies. Patients may have had a change in their health status, occupation, or dietary habits that could put them at greater risk for caries even if they currently do not show any clinical signs of caries⁹².

There are several aetiological caries risk factors that may be helpful when used in combination with the patients past caries experience. These include the extent of biofilm (plaque) coverage, diets high in fermentable carbohydrates (sugars) and reduced salivary flow⁸⁷. While dental biofilm is one of the main aetiologic factors for caries, its presence on a tooth surface does not necessarily mean that caries will occur. Plaque indices are ineffective predictors of future caries because caries typically develops in fissures and interproximal areas and most plaque indexes were developed to evaluate plaque formed on smooth surfaces associated with periodontal disease or gingivitis. Likewise, there is not adequate evidence linking individual patients with a high salivary bacterial load from cariogenic microorganisms, such as mutans streptococci, to a greater risk for caries. Patients with diets high in

simple sugars, in particular sucrose but also glucose and fructose, are at greater risk for caries. High consumption of starches is also of concern because they can be converted to sugars in the mouth by salivary amylase; however, starches are not strongly associated with caries. Saliva plays an important role in maintaining the health of soft and hard tissues in the oral cavity. A chronically low salivary flow rate has been found to be an indicator for increased risk of developing caries. Saliva flow diminishes with advanced age, but reduced flow may also be brought on by diseases such as Sjögrens or as a side-effect of many commonly prescribed medications. All patients who present with sign or symptoms of hyposalivation may be at increased caries risk as well as patients with motor or mental deficiencies may have difficulty implementing oral healthcare advice.

Other factors can place specific teeth and tooth surfaces at risk of caries: erupting teeth, particularly molars; teeth that may be hard to clean because of crowding; tooth surfaces covered by fixed (i.e., orthodontic brackets) or removable (i.e., partial dentures) appliances; have enamel defects; or faulty restorations. Teeth with exposed root surfaces are also prone to caries. While many factors can increase the risk of caries developing, there are some that are protective, such as fluoride exposure from all sources and dental sealants, which can reduce caries risk.

Guidelines to assess patients

Guidelines on how to characterize patients based on their caries risk have been proposed⁹². A number of different caries risk assessment systems involving paper forms or computer-based programs have been developed to help dentists assess caries risk using many of the factors covered above^{91–93}. It is important to note that caries risk-assessment systems need to be targeted at specific patient age groups as risk factors vary with age. Using these tools, patients can be placed in a risk category, then this information, along with other diagnostic

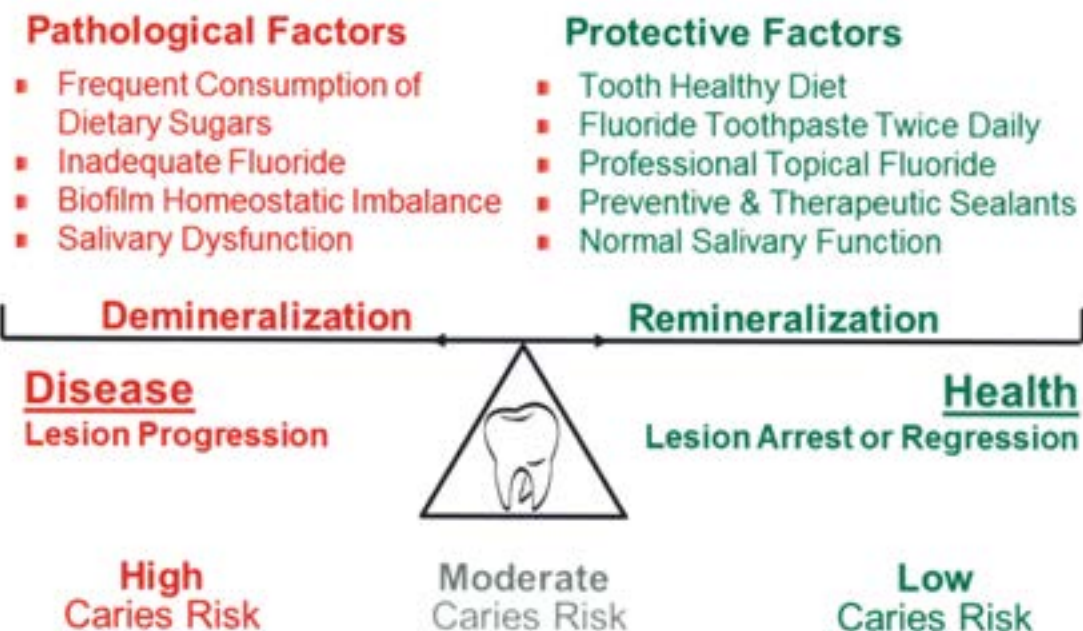
information, help inform the most appropriate treatment plan for the patient including the risk-based recall frequency. As a general rule, patients in a 'low' risk category will have had no incipient or cavitated primary or secondary carious lesions during the last two years and no change in the risk factors that may increase caries. Patients in a 'moderate' risk will have had one or two incipient or cavitated primary or secondary carious lesions in the last two years. Patients at 'high' risk will have had three or more incipient or cavitated primary or secondary carious lesions in the last two years. Patients could also be considered at moderate or high risk in the absence of any signs of active caries, if they have at recently one or more new factors that may increase caries risk, such as being diagnosed with hyposalivation.

Summary

In summary, there are many risk factors that can shift the balance towards health or disease and determine if a patient is a low, moderate or high caries risk (see Figure 6). Most important are three interrelated risk factors: the frequent and/or prolonged ingestion of dietary sugars which leads to acid production by biofilm bacteria; inadequate salivary flow rate which can result in prolonged sugar retention and pH depression; and poor oral hygiene which can lead to the accumulation of a thicker more pathogenic biofilm. Others important factors include suboptimal fluoride exposure to mitigate the risk for dental caries, malformed teeth due to poor nutrition, and socioeconomic deprivation and lack of adequate dental services. Risk assessment is a necessary component of good professional care and needs to be integrated in the caries management of every dentate patient. While many dentists apparently do some type of informal caries risk assessment, there remains the need for broadly adopted ideally electronic caries risk assessment aids/tools that can help dental professionals in establishing and documenting the caries risk status of their patients as well as tracking changes over time.

Figure 6 Effect of pathological and protective factors on caries risk status

Balancing Caries **Pathological** & **Protective** Factors



Modified from Pitts, 1983 & Featherstone, 1999

Section 6 Primary prevention (preventing disease in the absence of disease)

Introduction

The goals of dentistry should be to promote and preserve oral health and restore it only when it is impaired, hence the key role of prevention – primary, secondary and tertiary.

Primary prevention aims at preventing caries before it occurs. It is most effectively done by preventing exposure to what causes the disease, by modifying unhealthy behaviours and by increasing resistance to the disease. Secondary prevention comes into play when caries has progressed to a stage which is clinically detectable (non-cavitated lesion or white spot). It aims at reducing the impact of caries as early as possible by preventing further tooth destruction. It is accomplished through early detection and prompt intervention in order to reverse or arrest caries progression. Tertiary prevention applies in later stages of caries (cavitation) and it aims at softening its impact by preventing further hard tissue destruction, pulpal involvement and tooth loss, and restoring function and aesthetics.

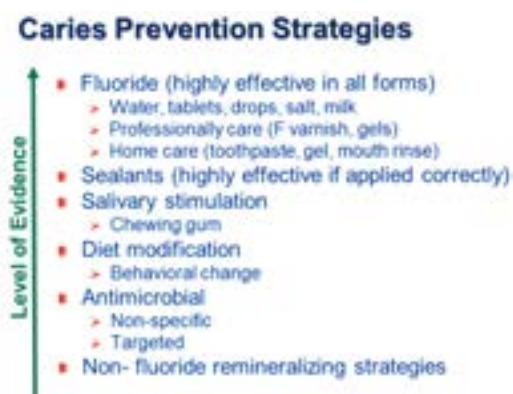
This Section will review available approaches for primary prevention (health maintenance) directed at mitigating the aetiological risk factors for dental caries and increasing protection against dental caries. It is important to note that the majority of the evidence is based on studies in children

and adolescents. The effectiveness of strategies involving the individual (patient), dentists and communities will be discussed not necessarily in the order of their importance but following the sequence of how they can be applied in dental practice. Figure 7 provides a listing of available strategies for primary prevention based on the author's assessment of the evidence supporting their effectiveness.

Strategies for primary prevention

The expression of caries can be mainly attributed to an individual's behaviours involving frequent ingestion of fermentable carbohydrates (sugars) and inadequate oral hygiene in combination with insufficient fluoride exposure. Therefore, primary prevention strategies need to be mostly directed at modifying or eliminating aetiological factors driving the caries process discussed in Section 2 and by increasing protective factors to arrest caries from progressing (fluoride, dental sealants). They must be based on the caries risk status of the patient and be consistent with the principles of evidence-based dentistry. Educating the public and patients on good oral health behaviours and thus empowering them to be responsible for their own health is the ultimate goal of primary prevention. This Section focuses on the role dentists can play in primary caries prevention as direct contact with patients allows them to personalize primary preventive strategies

Figure 7 – Ranking of evidence supporting caries prevention strategies



for each individual. Public health, community and school-based educational and interventional programmes are also essential in improving oral health outcomes. They are mainly addressed in the Advocacy Toolkit⁹⁴.

Strategies to modify or eliminate etiological factors

Biofilm

The dental biofilm plays an essential role in caries initiation and progression and toothbrushing and flossing are the main means for controlling biofilm formation. The evidence supporting toothbrushing and flossing alone as a means to prevent dental caries however is weak and conflicting^{95,96}. The benefit of toothbrushing can only be associated with the use of fluoride toothpaste at concentrations 1000 ppm F and higher⁹⁷. The use of antimicrobial agents in the form of mouthrinses, gels and varnishes have not proven to be effective in reducing caries, with the one exception of chlorhexidine/thymol varnish every three months to reduce the incidence of root caries in adults⁹⁸.

Professional dental prophylaxis (rubber cup) for biofilm removal at recall visits or before application of professionally applied fluoride is of no benefit for the prevention of caries in children⁹⁹. There has recently been a paradigm shift from just trying to remove the biofilm to emphasis on maintaining a healthy biofilm by modifying dietary behaviors (see below), and the use of prebiotics¹⁰⁰ and probiotics¹⁰¹, although sufficient evidence is lacking^{100,102}.

Diet

A recent systematic review has concluded that caries is much less likely to occur in the absence of dietary free sugar intake above a threshold of 5% of energy intake³⁵. This threshold has been adopted as the basis for WHO¹⁰³ and SACN guidelines. Below this threshold, individuals are at very low risk of developing caries. However, there is still limited evidence that one-to-one dietary interventions to restrict sugar intake in a dental setting are effective¹⁰⁴. Despite the lack of sufficient evidence, controlling sugar consumption at the individual patient level remains a justifiable part of caries prevention. Sugar consumption should be assessed

and patients advised to limit the frequency of sugar exposures to meals and to substitute sugar-containing foods and beverages with alternatives that are less cariogenic.

Salivary stimulation/optimization

The saliva flow rate and composition are important aetiological host factors that modify the caries process²⁷. Patients with salivary dysfunction are at risk of serious adverse effects on their oral health, especially greatly increased dental caries¹⁰⁵. Chewing sugar-free gum for 10-20 minutes after meals has been recommended to reduce coronal caries⁹⁸. Gustatory, masticatory, or pharmaceutical stimulation has also been recommended as a means to reduce the incidence of caries in patients with Sjögren disease, although the strength of the recommendation was rated as weak due to a lack of evidence in this patient population¹⁰⁶.

Strategies to increase resistance to caries

Fluoride

Fluoride in a wide variety of forms and delivery systems has been proven to prevent dental caries. Community water fluoridation is the most cost-effective public health (population level) means of preventing caries and has been adopted by many countries worldwide. However, its use in many parts of the world is limited by infrastructural and political obstacles. Fluoride toothpaste is the mainstay of primary prevention and is the most widely used form of fluoride delivery worldwide for all stages of life (Table 1). The effectiveness of fluoride dentifrices has been documented in numerous clinical trials and systematic quantitative evaluations^{97,107}, which provide the highest standard of evidence for the effectiveness of fluoride dentifrice.

Over-the-counter fluoride toothpaste products range from 250 ppm to 2800 ppm fluoride (F) worldwide, and there is a wide variance in the type (F compound and concentration) and the quality of fluoride toothpaste available to consumers. This is influenced by the regulatory environment in each country, guidance from dental professional associations, the ability of established oral care companies to market their fluoride products and

economic considerations. The actual bioavailable fluoride may also be much lower if a toothpaste product is not properly formulated or has exceeded its shelf-life^{108,109}. The preventive effect of fluoride toothpaste has been found to increase significantly with higher fluoride concentrations⁹⁷. Lower concentration fluoride products <1000 ppm are being targeted at children based on concerns that ingestion of fluoride toothpaste by very young children can increase the risk of dental fluorosis. However, recent systematic reviews have not supported this approach^{110,111}: the use of low concentration (<600 ppm F) toothpastes increased the risk of developing caries and there is a lack of evidence that they decreased the risk of aesthetically objectionable fluorosis¹¹².

Table 1: Recommendations for best practices based on available evidence for fluoride toothpaste use¹¹³

Action	Recommendation
Brushing frequency	<ul style="list-style-type: none"> 2x/day (morning and before bed)
Amount of fluoride toothpaste	<ul style="list-style-type: none"> >2yrs: thin smear, ½ a pea (0.05-0.1g) 2-6yrs: pea size (0.25g) <6yrs: full length of toothbrush (1-1.5g)
Brushing time	<ul style="list-style-type: none"> minimum 2 minutes
Post-brushing	<ul style="list-style-type: none"> spit, do not rinse with water
Supervised brushing	<ul style="list-style-type: none"> up to the age of 8 years

For individuals at higher risk of developing dental caries, fluoride mouthrinses are recommended in addition to fluoride toothpaste. Cochrane Collaboration systematic reviews have reported that supervised use of fluoride mouthrinse by children is associated with a clear reduction in caries increment¹¹⁴ and can also reduce dental caries irrespective of exposure to water fluoridation¹¹⁵.

There is limited evidence of an anticaries benefit for home use prescription-strength (5000 ppm

F) fluoride gel or paste application twice daily¹¹⁶. The American Dental Association (ADA) expert panel recommended their use for individuals at elevated risk for developing caries aged 6 years and older and for individuals with root caries and also recommended the home use of high concentration fluoride mouthrinses at least weekly in 6-18 year olds based on favourable evidence and for both coronal and root caries in those older than 18 years based on experts’ opinion¹¹⁶.

There is a moderate level of evidence to support professionally applied topical fluoride treatments in higher risk individuals. Professional application of fluoride gels has been associated with a substantial reduction (21%) in caries (DMFS)¹¹⁷. Application of fluoride varnishes two to four times a year, either in the permanent or deciduous dentition, has been associated with a substantial reduction in caries (DMFS), on average 43% and 37%, respectively¹¹⁸.

Dietary fluoride supplements

The use of fluoride drops and tablets as a means of fluoride delivery to individuals living in communities that have less than optimal fluoride levels in the water is somewhat controversial. An ADA expert panel has recommended prescribing fluoride supplements for children whose primary source of water has deficient levels in the water and only for children who are at high risk of developing caries¹¹⁹. However, these recommendations have some limitations for worldwide application as background fluoride levels are not readily available to clinicians. In a review of available evidence, the Scottish Intercollegiate Guidelines Network (SIGN) concluded that there was “insufficient evidence to recommend the use of fluoride drops or tablets against a background of fluoride toothpaste use.” In sum, there is a need to strike the correct balance between delivering an optimal risk-based level of fluoride and concerns about children under six developing dental fluorosis. Fluoride toothpaste being a more generally accepted means of delivering fluoride, careful consideration needs to be given before fluoride supplements are recommended.

Dental sealants

Use of dental sealants for preventing the initiation (primary prevention) or progression (secondary

prevention) of dental caries on occlusal surfaces of permanent molars has strong evidence in both clinical and school settings^{120–123}. The effectiveness of one type of sealant material over another has not been conclusively established¹²¹. However, based on limited evidence, resin-based sealants can be considered to be the material of choice, while glass ionomer cement are preferred when there are concerns that moisture control may compromise sealant placement, such as partially erupted teeth or for uncooperative patients^{122–124}. Given their proven effectiveness, dental sealants remain one of the most underutilized preventive strategies worldwide. Concerns that a tooth with a partially lost sealant may be at a higher caries risk than unsealed teeth appear to be unfounded¹²⁵. In settings where caries prevalence is low and other means of prevention are effective, the use of sealants may be limited to secondary prevention, while in settings where caries prevalence remains high or is increasing, the use of sealants for primary prevention is still indicated¹²⁴.

Based on a recent updated Cochrane review there is limited evidence indicating resin-based fissure sealants are superior to fluoride varnish applications for preventing occlusal caries in permanent molars, and also for supporting the benefits of the combined use of resin-based sealant and fluoride varnish over fluoride varnish alone¹²¹.

Non-fluoride remineralizing strategies

A wide array of non-fluoride remineralization systems have been developed that are intended for use either in place of or in combination with

fluoride^{100,126}. However, there is no clinical evidence supporting their use in primary prevention.

Regular recall visits

Health behaviours involving attending regular dental check-ups provide the opportunity for caries risk assessment and professional interventions. The 6-month recall has become the standard in many parts of the world; however, there is a lack of sufficient evidence for or against this practice^{127,128}. While there is a growing consensus that the frequency of recall visits should be risk-based, the evidence remains weak.

Summary

Fluoride is the most widely accepted and effective means of primary prevention, at the levels of both populations and individuals. There is a need to match fluoride exposure (vehicle, concentration and frequency) with the patient's caries risk status, while recognizing that in some cases the goal of completely preventing dental caries cannot be achieved without also mitigating the etiological factors (dietary sugars, biofilm, salivary dysfunction). The optimal level of fluoride exposure is the lowest level that will maintain oral health without safety concerns; however, there is no one optimal fluoride exposure for all individuals, and the only way this can be determined is by establishing the caries risk status of the patient. Dental sealants are a highly effective strategy for preventing occlusal caries, but remain underutilized.

Section 7 Secondary prevention (early detection and control of initial-stage disease)

Introduction

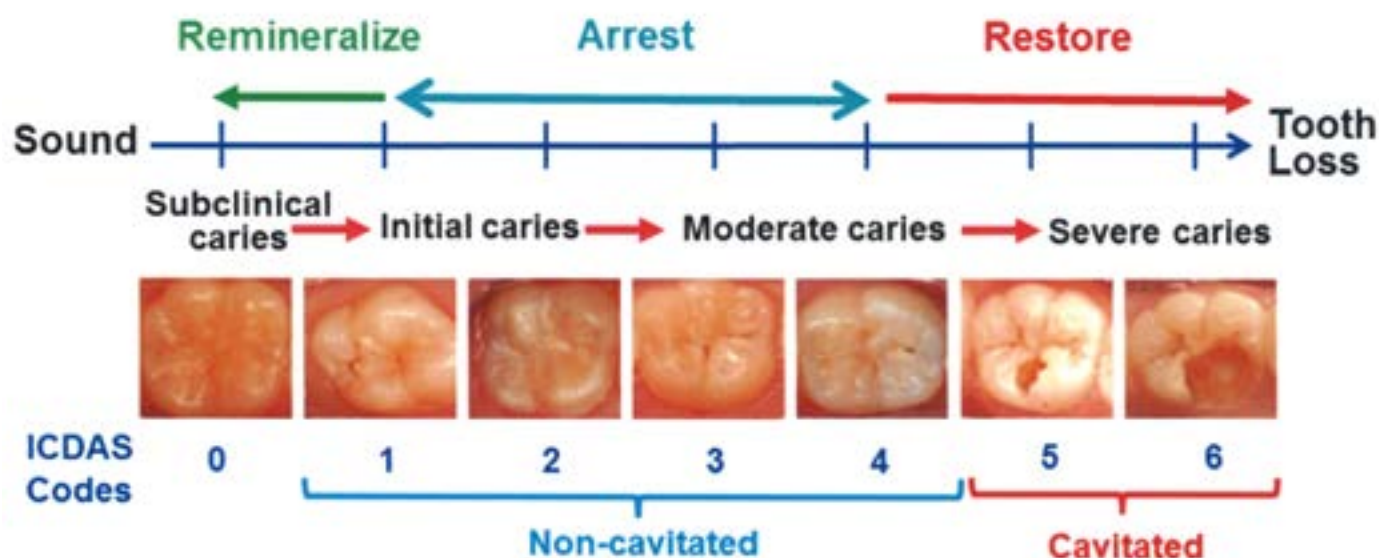
As discussed in Section 6, secondary prevention comes into play when caries has progressed to the stage that it is clinically detectable (non-cavitated lesion or white spot), but not so far that the lesion has cavitated requiring operative intervention (tertiary prevention). The goal is to reduce the impact of caries as early as possible by preventing further tooth destruction (demineralization) and possibly reversing the caries process in favour of remineralization. Secondary prevention requires oral health professionals to accurately detect and assess the early stages of the disease (non-cavitated lesions) (see Section 4)¹²⁹, and the initiation of prompt intervention in order to reverse (fluoride) or arrest caries progression (fluoride, sealants). It is important to recognize that the exact transition between primary and secondary caries prevention is not that precise because many teeth that appear to be clinically sound may have subclinical active caries lesions that will eventually become clinically evident

without instituting preventive measures (Figure 7), and many of the same interventions are applicable to both primary and secondary prevention, such as biofilm control, professional and home-use topical fluoride and sealants. Furthermore, the transition from secondary prevention to tertiary prevention also has some overlap in regard to possible interventions (Figure 8), while also recognizing that the evidence is building supporting non-invasive (biological) methods of managing cavitated lesions in primary and permanent teeth¹³⁰.

The clinical decision making process to determine the best evidence-based interventions for patients must include early caries detection and assessment, caries risk assessment, establishing a caries diagnosis and prognosis at the level of the patient and tooth surface⁸⁶. Secondary prevention strategies can be directed at the patient level (professionally applied topical fluorides, prescription strength fluoride paste, gel or rinse) or the tooth surface level (dental sealants, improved biofilm removal). A

Figure 8 – Caries diagnosis and management continuum

Caries Continuum



recent policy document by the European Academy of Paediatric Dentistry stated that there was overwhelming agreement that a spectrum of non-invasive, micro-invasive and minimal-invasive dental caries management methods and procedures are needed in paediatric dentistry for the treatment of early caries lesions in children and young adults¹³¹. This section will review the evidence supporting strategies for secondary prevention available to oral health professionals.

Early caries detection

A key component of secondary prevention is the accurate detection and assessment of early caries lesions. Patients for the most part are not capable to detecting the early stages of dental caries and, unless effort is made by oral health professionals to remove the dental biofilm from teeth, early caries lesion can also go undetected during routine oral examinations. Dental caries can only occur on tooth surfaces chronically covered by dental biofilm, and thus the biofilm must be removed to visually detect the early stages of caries. Most advanced caries classification systems like ICDAS required thorough tooth cleaning to detect non-cavitated lesions (ICDAS Codes 1-4) and the use of compressed air to detect the earliest stages of caries (ICDAS Code 1). The FDI Matrix⁴ and the ADA Caries Classification System⁶² have incorporated major elements of ICDAS into their systems. Furthermore, ICDAS has been incorporated as part of European Academy of Paediatric Dentistry best clinical practice guidance for management of early lesions policy document¹³¹. It's essential that the activity state of early lesions is also determined as these lesions may be active (progressing), arrested or regressing, and if arrested, lesions do not require further intervention^{82,83,129}. ICDAS also includes assessment if lesions are active or inactive.

Non-invasive/surgical/operative strategies

Ideally the management of early caries lesions should involve the least invasive approach that prevents disease progression and that empowers the patient to improve and maintain their own oral health. Oral health professions can play a critical

role in educating patients in evidence-based strategies that mitigate the progression of dental caries and in providing non- or micro-invasive interventions, which may arrest or reverse the caries process. As long as the surface layer of the lesion is mostly intact many of the same strategies involved with primary prevention are applicable for secondary prevention.

Strategies to modify or eliminate aetiological factors

The dental biofilm and diet are modifiable aetiological factors. If patients improve their oral hygiene such that they effectively remove the biofilm over active non-cavitated lesions on a daily basis, the lesions should arrest and possibly regress. Erupting molars accumulate significantly more dental biofilm than fully erupted teeth, and thus the importance of biofilm control and other interventions have been stressed during this critical time¹³². Furthermore, if patients change their dietary behaviours and reduce exposure of free sugars to below a threshold that would shift the caries process from demineralization in favour of net remineralization, this could also lead to lesion arrestment or regression. Evidence that these measures are effective interventions on their own is very limited because the vast majority of studies include the use of fluoride¹³³.

Strategies to Remineralize Caries Lesions or Arrest Caries Progression

Fluoride

Based on a systematic review of non-surgical management methods, fluoride interventions including varnishes, gels, and toothpaste were found to have the most consistent benefit in decreasing the progression and incidence of non-cavitated caries lesions¹³⁴. A recently reported systematic review concluded that professionally applied 5% NaF varnish can remineralise early enamel caries and 38% silver diamine fluoride is effective in arresting dentine caries based on limited evidence¹³⁵.

Non-fluoride agents

Studies using xylitol, chlorhexidine, and CPP-ACP vehicles alone or in combination with fluoride therapy are very limited in number and in the majority of the cases did not show a statistically significant reduction¹³⁴.

Therapeutic dental sealants

Several systematic reviews have concluded that sealing non-cavitated caries lesions in permanent teeth is effective in reducing caries progression^{122,134,136}. Sealants have been shown to be effective in reducing the number of viable bacteria when placed over carious lesions and the reduction increases with time¹³⁷. In a long-term study involving teeth with more extensive lesions, caries did not progress over a 10-year period under dental sealant placed over cavitated lesions that were no more than halfway through dentin of the tooth¹³⁸.

Micro-invasive strategies - resin Infiltration

Systematic reviews have indicated that resin infiltration appeared to be an effective method to arrest the progression of non-cavitated caries proximal lesions^{139,140}, and to be significantly more effective than non-invasive professional (fluoride varnish) or oral hygiene advice (to floss)¹⁴¹. Some concerns have, however, been raised regarding technique sensitivity for approximal sites, and that the surface layer of enamel is removed as part of the procedure.

Minimal-invasive surgical procedures

The use of minimal-invasive techniques has been advocated to preserve tooth structure^{142,143}. However, there is no evidence that minimally invasive surgical procedures can lead to better long-term outcomes

than for more traditional restorative procedures and improve the re-restoration cycle¹⁴⁴.

Root caries

The application of 5% NaF varnish every 3 months was recommended as the best choice for secondary prevention in patients with root caries lesions, and the daily use of prescription strength 1.1% NaF paste or gel was considered the best alternative¹⁴⁵. Based on meta-analysis of limited evidence prescription strength paste (1.1% NaF) and professionally applied chlorhexidine or silver diamine fluoride varnish may inactivate existing and/or reduce the initiation of root caries lesions¹⁴⁶.

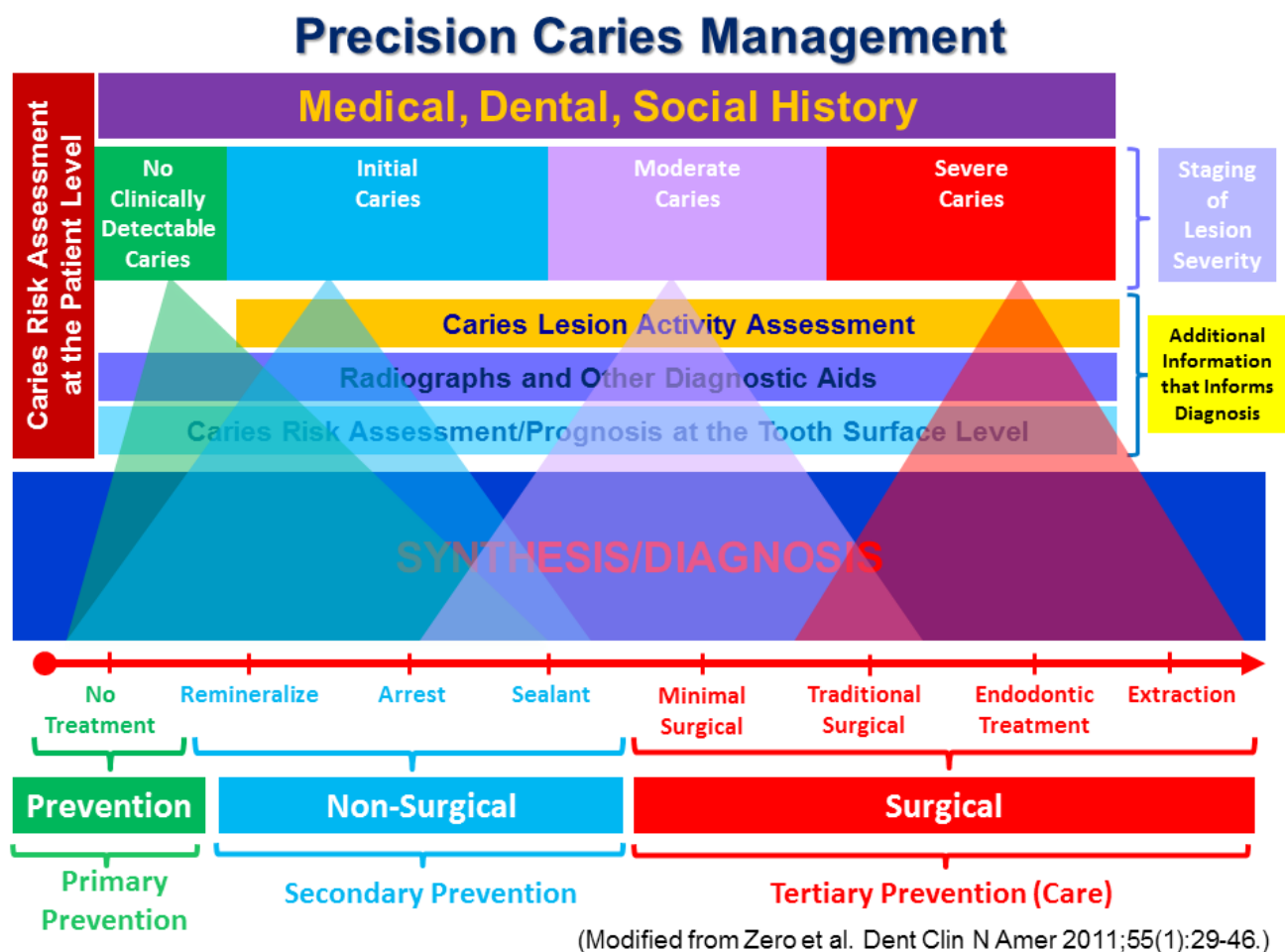
Caries Associated with Restorations or Sealants (CARS)

It is recommended to either seal or repair defective or carious margins of restorations wherever possible¹⁴⁷. This also applies to defective or lost fissure sealants, which require maintenance/repair only.

Summary

Secondary prevention strategies to arrest or reverse caries progression at the non-cavitated lesion stage are an important aspect of overall caries management. Eliminating the need or delaying surgical intervention and the placement of restorations can have important lifetime oral health benefits for patients. Clinical decisions regarding non-cavitated lesions can range from no intervention to traditional surgical intervention (*Figure 9*). The extent of lesion severity and activity, and caries risk status, potential for compliance and preferences of the patient need to be taken into account to make the best evidence-based decision as to the appropriate level of care.

Figure 9 – Precision caries management



Section 8 Preservation of tooth tissue

Introduction

Over recent decades there has been an increasing and fundamental understanding of the importance of retaining natural tissue wherever possible, unfortunately this has not been mirrored by effective action to move away from a period of evolution in dentistry where the technical ability to cut and replace tooth tissue (and be paid for it) has remained as the norm, long after the case for a more biological, long-term and preservative approach has been made and agreed.

The first Section of this paper outlined the evolution of caries management philosophies and evolution from extractive to restorative to philosophy, through of recognition of the preservation of natural tissue. The evidence to making the last step has been with us for decades coming from reviews in the 1990s of studies conducted in the 1980s¹⁴⁸. This priority to move to “Minimal Intervention in the Management of Dental Caries” and examples of how it may be achieved across a range of settings (for example using remineralization of non-cavitated lesions of enamel and dentine, minimal operative intervention of cavitated lesions, using the “ART” technique when appropriate, and using limited repair of defective restorations) was made very clear in FDI Policy statement issued in 2002¹.

However, 14 years on, progress has been slight in many countries. The arguments to move from operative to non-operative/preventive treatment of dental caries in clinical practice were in place and reviewed back in 2004⁶, but then as now there is very wide variation across countries and health systems in both the speed and extent of progress being made in achieving this transition. This is despite the production of a further, comprehensive FDI Policy statement in 2012 on Caries Classification and Management Systems which again supported the preventive and minimally invasive approach³.

Approaches to caries management in the 21st Century

In May 2012 a group of cariologists, dentists, representatives of dental organizations,

manufacturers, and third party payers from several countries, met in Philadelphia, USA to define a common mission; goals and strategic approaches for caries management in the 21st Century. Following wide-ranging debates in which many divergent views on classification systems and other matters of detail were expressed and heard, agreement on a number of overarching and important themes emerged¹⁶. These included that:

- For decades “new” scientific evidence on caries and how it should be managed has been discussed and re-discussed among experts in the field. However, only limited change has been achieved (except in some Scandinavian countries) in the models of caries management and reimbursement used - which have continued to be heavily skewed towards ‘drilling and filling’.
- There has been little overall agreement on what constitutes caries or on when to surgically intervene in its clinical management.
- The participants in the workshop re-defined an overall mission for all caries management approaches, both conventional and new. It was agreed that the mission of all systems should be **“to preserve the tooth structure, and restore only when necessary”**.
- This clarified mission should mark a pivotal line for judging when to surgically intervene and when to arrest or remineralize early non-cavitated caries lesions.
- Even when restorative care is necessary, the removal of hard tissues should be lesion-focused and aim to preserve, as much as possible, sound tooth structure.
- Continuing management of the aetiological factors of caries and the use of science-based preventive regimens will also be required to prevent continuing recurrence and re-restoration.
- These changes have been debated for over a decade, so action is needed now!

- It is time for all oral health professionals to focus on the promotion of oral health and preservation of sound teeth rather than counting the number of surgical restorative procedures provided.

This over-arching direction of travel was entirely consistent with the International Caries Classification and Management System (ICCMS™), one of the most intensively developed systems presented at the meeting. The ICCMS™ example provides methods for the staging of the caries process and enabling dentists to manage caries in a way that preserves healthy tissue¹⁵. The detail of the System has been refined and developed further over the last four years and is presented as a worked example in more detail in Section 9, but it is important to realize here that one of the System's integral aims is to preserve tooth structure with non-operative care at more initial stages and conservative, tooth preserving, operative care at the more extensive stages of caries.

Figure 10 shows an overview of the ICCMS™ Management Element which is designed to help dentists provide Personalised Caries Prevention, Control & Tooth Preserving Operative Care. The approach is to integrate the clinical management of: **caries the disease** (preventing new caries at sound sites), **caries lesions** (wherever possible through the non-operative care of lesions, or, if unambiguously required, through the Tooth Preserving Operative Care (TPOC) of Lesions) and **caries risk** (by assessing and reviewing caries risk and modifying treatment and recall decisions accordingly).

Figure 10 Integrated Caries, Lesion and Risk Management

ICCMS™
Approach to Integrated Caries, Lesion and Risk Management



It is important when discussing the issue of preservation of tissue to consider the clinical management of lesions at BOTH the enamel AND dentine levels; too often groups have examined only one end of the caries continuum and ignored the other. There have been encouraging developments in dental education in which the more patient-centred holistic view has emerged. An excellent example is seen in the European Core Curriculum in Cariology for undergraduate dental students^{17,18}, in which the balance between preventive and tooth preserving non-operative intervention on the one hand and minimally invasive surgical intervention on the other is explicitly discussed and taught. This European initiative is now having a wide uptake in some countries in Latin America¹⁹, Asia and, most recently, across US Dental Schools²⁰. Holistic minimally interventive methods for caries management in dental practice have been well communicated¹⁴⁹ and the broader minimally interventive approach to dental practice has been well articulated⁸⁵.

A very recent paper from an international group has looked at both the terminology and contemporary evidence around many of the procedures available for managing carious lesions in a tooth preserving way, although with a specific and important focus on caries removal end of the spectrum⁷⁷. Key elements from this initiative are:

- Advancing the idea that the term *dental caries management* should be confined to control of the disease through preventive and non-invasive means at the patient level while *caries lesion management* is confined to controlling the disease symptoms at tooth level, be that by non-invasive treatments designed to be used on lesions at the surface level or by methods involving surgical removal of tissue at the surface or tooth level.
- Very useful grouping of the available clinical activities on the basis of tissue removal (with a focus on dentine) into four categories:
 - No removal of carious tissue
 - Selective removal
 - Stepwise removal
 - Non-selective removal of carious tissue

- Consideration of new and not so new treatment options, such as therapeutic sealants, ART and the Hall Crown, as well as the best options for minimizing damage to future pulp health.

Consideration of this topic must include mention of the undesirable consequences of repeat restorative dentistry on both pulp health and risk of tooth fracture, as well as the long-term economic costs to individuals and societies. There has been dramatic progress made in some aspects of dental materials research over recent decades, but the danger of looking for a technical solution to solve a biological problem related to a preventable disease must not be underestimated.

Other wider aspects of importance to this topic include safety and environmental impact. The ratification of the Minamata Convention on the use of Mercury will have an impact around the world in coming years. The profession needs to avoid “doing environmental harm” with restorative materials and there are concerns that, even if dental amalgam is entirely replaced with the use of composite resins, different eco and bio-hazards may result. This is why in the roll-out and implementation activities post-Minamata, the importance of prevention and a rational, minimally interventive, restoration strategy is important in all countries.

Section 9 Evidence based clinical caries management: a systematic approach

Introduction

This Section provides a case study, a worked example, of using a systematic approach to assemble a comprehensive but practicable scheme to deliver evidence based clinical caries management. The intrinsic logic of evidence-based health care is to move towards adopting best evidence by building on the strongest research findings, amalgamating and improving and harmonizing systems, rather than allowing endless narrow competition between so called minority systems - which may never be sufficiently evaluated in multiple settings. Innovation is very much allowed of course, but the default position in many health settings is now to develop and adapt best evidence incrementally through collaborative improvement of an open system.

Case study: ICDAS/ICCMS™/GCCM systems

The case study referred to in this Section concerns the ICDAS/ICCMS™/GCCM systems. The **ICDAS Foundation** (www.ICDAS.org) is a charitable body with an International Board that oversees all three elements of this work, which has in recent years mirrored the recommendations of the 2012 FDI Policy Statement in this area. The Foundation have continued the “development and adoption of a caries lesion classification system” (which is the **ICDAS** element (*International Caries Detection and Assessment System*) starting from 2002) as well as producing “...a separate caries management system” (which is the **ICCMS™** (*International Caries Classification and Management System*) “..including risk assessment and prevention, that are able to describe and document the total caries experience at a population and an individual level”³. The Implementation of ICCMS™ is now, since a launch at Kings College London in 2013, being addressed by a third complementary network under the ICDAS Foundation’s umbrella, the **Global Collaboratory for Caries Management** (GCCM). The Vision of the

ICDAS Foundation (updated in November 2015) is: *To improve human health worldwide by the prevention and control of dental caries throughout life.*

The **ICCMS™** brings together and integrates much of the material and evidence summarised so far in this White Paper – particularly in Sections 3, 4, 5, 6, 7 and 8. The System has been repeatedly identified as the most comprehensive and widely evaluated of the available alternatives⁴ and with the various formats of the ICDAS criteria, has been used in hundreds of publications in many countries around the world (see ICDAS in the literature – www.ICDAS.org). The Systems have evolved and adapted since ICDAS was developed and peer reviewed a decade or more ago^{55,56,79}.

The additional reference list at the end of this Section gives a snapshot of the evolution of ICDAS and ICCMS™.

ICCMS™ is a health outcomes focused system that aims to maintain health and preserve tooth structure, by using a simple form of the ICDAS Caries severity and activity **Classification** model in order to derive an appropriate, personalised, preventively based, risk-adjusted, tooth preserving **Management Plan**.

Overview of ICCMS™ - International Caries Classification and Management System

The ICCMS™ is designed to help effectively manage caries in a dental clinic or practice in 2016 and beyond. The system was trademarked by the charity some years ago (on advice) in order to be able to keep it as an open system available to all.

Key steps along the evolution of ICCMS™ have been the:

- Recognition of the need for a systematic approach to bring together complex strands of activity needed to manage this complex and multi-factorial disease.

- Link between the histological extent of caries spreading within the tooth and the visual appearance of clean dry tooth surfaces.
- Expanding the continuum of caries to include health and wellness, initial lesions that can be arrested and reversed at one end and also capturing pain as well as sepsis at the more severe end, including the PUFA Index where applicable.
- Ensuring that there is clarity and inclusiveness across the four Domains of Practice, Education, Research and Public Health – which were identified at the start⁵⁵.
- Creating from the start a range of “wardrobes” from which it was possible to select the most appropriate clothing for the task at hand, recognising that this is not a case of one size fits all.
- Involvement of the many international colleagues and organisations who have come together to share expertise and maintain and develop the system. We acknowledge effective teamworking with ORCA, IADR, FDI, ADEE, ACFF and other groups who have helped in the development.
- Key resources along the way have been the website (www.ICDAS.org), e-Learning Courses translated into multiple languages, the Karger Monograph published in 2009, and the Supplement to the European Journal of Dental Education published in 2011 and the epidemiology data collection tool accessible for free from the website.
- The demonstration by Evans and co-workers in Australia that this approach used in practice can achieve cost effective preventive benefits in a randomized clinical trial setting over three years and further, that the benefits in reduced caries risk and reduced restorative care are then sustained over a further four years’ period¹⁵⁰.
- More recent implementation tools are considered in Section 12 on supporting change.

The ICCMS™ - Wardrobe and the four “Domains”

Figure 11 shows in the Centre the 2016 version of the Wardrobe. It has proved essential to provide the central option as three levels of caries and

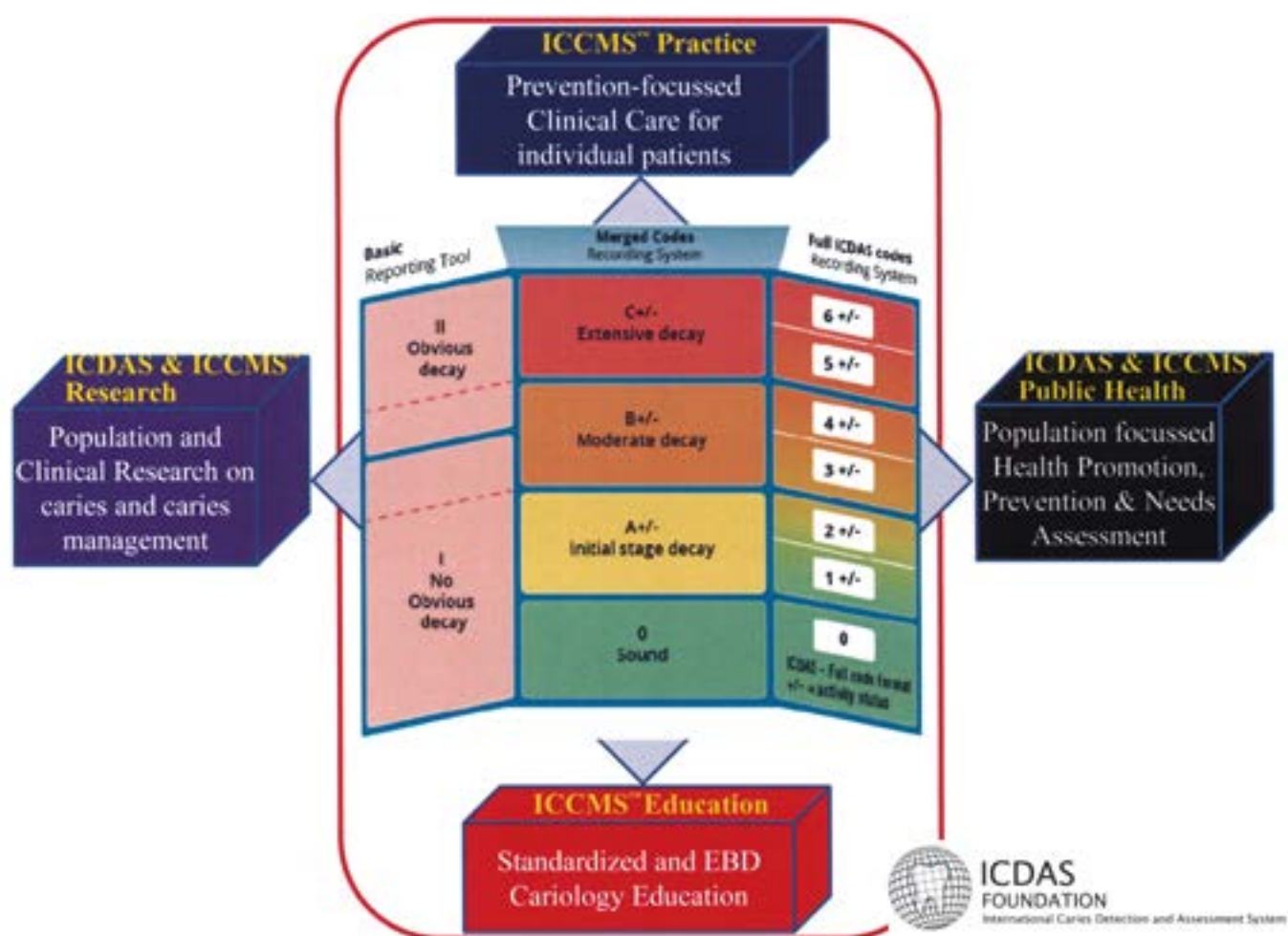
“sound” as this is the most straightforward way for many dentists to start using the system. The so-called merged codes or condensed codes system has proved to be sufficient for many dentists, although some do migrate to using the full six ICDAS codes for caries which is offered as an option. It is important to realize that it is possible to collect information at the more detailed levels and then calculate results for the merged codes format or the Basic Reporting Tool (Obvious Decay and No Obvious Decay at the WHO Basic Methods level). It is also possible (should users need to) to calculate conventional DMF statistics and add the PUFA Index.

Around the outside of this common Wardrobe are the four Domain of ICDAS. These represent the different and often multiple uses to which the System is put.

Progress in the Domains

- *Progress with Research* - the criteria have become a de facto standard at many research meetings and in many publications. The IADR Global Inequalities Research Agenda Group was instrumental in the development phases of ICCMS™
- Progress with Education – the link with the European Core Cariology Curriculum has been mutually beneficial and many Dental Schools around the world now teach ICDAS criteria and are increasingly learning about ICCMS™.
- Progress with Practice – the take up of the System in Practice has been slower than in the other Domains – although there are some exceptions (such as Japan). The launch of the Guide for Practitioners and Educators is improving take up and links to practice software systems now being trialled are expected to accelerate things further.
- Progress with Epidemiology – after the great IADR supported work by Rita Villena and colleagues in mapping caries in infants in Latin America, there are further successes with National Surveys in Iceland, England and Portugal being undertaken and a broad take up in a number of European Countries and new interest from Brazil.

Figure 11 - Four domains of the International Caries Classification and Management System ICCMS™



- It is also important to appreciate that the roll-out of such systems does not have to be paper-based or IT-based, it is imperative that there is room for local choice and adaptation, as long as the core scientific principles are respected.

A recent development of note is the publication of *Best clinical practice guidance for management of early caries lesions in children and young adults: an EAPD policy document*¹³¹. This initiative from the European Academy of Paediatric Dentistry (EAPD) used a rigorous appraisal of evidence throughout. They concluded that “The detection and management of non-cavitated caries is an essential aspect of preventive dentistry. Therefore, the EAPD encourages oral health care providers and caregivers to implement preventive practices that can arrest early caries and improve individual and public dental health. Further in Caries detection and

diagnosis - the EAPD Guidelines recommend the use of condensed ICDAS”.

Implementing ICCMS™ in Practice and Education

In order to make the ICCMS fit for use in daily practice a group of 75 interested academics, clinicians and interested expert parties were assembled at Kings College London in June 2013. This was the launch of the **Global Collaboratory for Caries Management (GCCM)**. They worked for four days in sub-groups and jointly reviewed both the evidence and draft material to build a user-guide to ICCMS™. Over the next 18 months the authors developed and refined the Guide for Practitioners and Educators. It was found that some users wanted a full 40 pages guide with 40 pages of full appendices, others just wanted the core document,

whilst still others wanted only a 12 pages Quick Reference Guide. The material was published in December 2014 and is available for download.

ICCMS™ Guide available for free download from www.icdas.org

- [ICCMS™ Guide for Practitioners and Educators UK Version](#)
- [ICCMS™ Guide for Practitioners and Educators UK Version \(with appendices\)](#)
- [ICCMS™ Guide for Practitioners and Educators US Version](#)
- [ICCMS™ Guide for Practitioners and Educators US Version \(with appendices\)](#)

Quick Reference Guide available from www.icdas.org

- ICCMS™ Quick Reference Guide for Practitioners and Educators

Interestingly, after release of these materials it has become clear that some other potential users want a *Very Quick Reference Guide* of only one to two pages. For this Group **ICCMS™** has developed a **The 4D approach for Practice and Education**.

Figure 12 shows how ICCMS™ can be implemented as the “4D Caries Management Cycle”. This is a one to two pages’ communication tool for the dental team, which is in development. The essential 4Ds are:

1. **DETERMINE** (caries risk)
2. **DETECT & ASSESS** (lesions and their activity)
3. **DECIDE** (personalised care plan, at both patient and tooth levels)
4. **DO** (the right intervention(s) at the right time(s) to

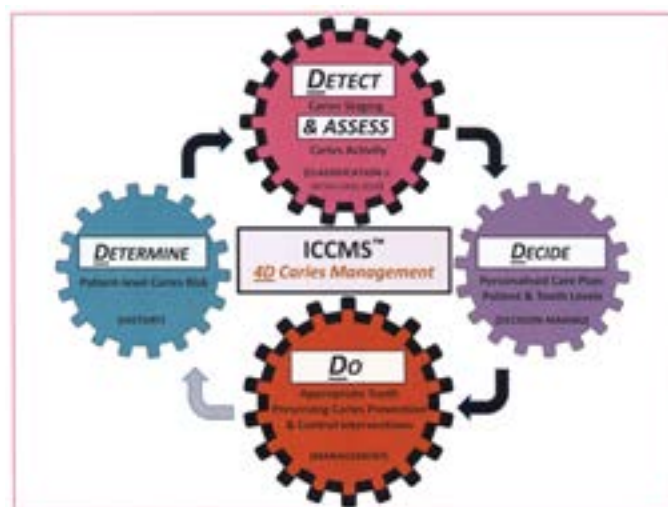
maintain tissue and health) and schedule risk-based reassessment and review (NICE, 2004)¹⁵¹

This Figure, with a single image, seeks to communicate the essential cyclical steps of the International Caries Classification and Management System. It has been successful so far in explaining to new users what exactly they are being asked to do and to help them assess the magnitude of any change in approach they may have to make in order to implement such a System.

It is important to consider the many different settings and countries such a Management System may be used in and that the detail and sequence of steps may have to adapted locally. The details can and should be adapted, as long as the key steps are retained and done well.

ICCMS™ is an outcomes-focused system and these issues are discussed further in Section 13.

Figure 12 - ICCMS™ 4D Caries Management



Additional references Section 9^{15,18,55,56,59,61,66–70,79,83,152–162}

Section 10 Remuneration for appropriate caries prevention and management

Introduction

This Section considers how Dentists are remunerated (compensated) for providing *appropriate* Caries Prevention (both assessment, advice and individual preventive procedures) *and* Management (that is both non-operative *and* operative management, as required) both now and in the future. The focus is how evidence-based care can be remunerated fairly, efficiently and avoiding current perverse incentives.

Traditionally, this has been a rather contentious subject which has often been avoided; yet time and again international groups looking at barriers to change in this field have stated that lack of reform of remuneration systems has provided the biggest obstacle to change. It is encouraging that in both the CPP *Summit* and Workshop held at FDI World Dental Congress in Bangkok in 2015, key stakeholders all advised that it is now time that this barrier to change was recognized, confronted and overcome.

The requirements to deliver for caries: *risk assessment, clinical detection and assessment, primary and secondary prevention and, only where indicated, tooth preserving operative interventions in an integrated and patient-centred way* which is advocated in the previous Sections as optimal, evidence based care can only be achieved in a sustainable way by the dental profession if payment systems are aligned with this type of care. Unfortunately, remuneration systems in most countries (with some notable exceptions) have not kept pace with recommendations for best clinical practice and this mismatch perpetuates a style of practice which is biased towards surgical intervention and payments chiefly for restorative care.

A parallel challenge is the lack of robust data on the comparative clinical and economic effectiveness of existing and newer alternative clinical systems and remuneration models. A Cochrane systematic review examined the effect of different methods of remuneration on the behaviour of primary care dentists¹⁶³. They

concluded that, while financial incentives may produce changes to the clinical activity undertaken, the quality and volume of the evidence available was either low or very low for all outcomes. Another systematic review on factors that drive dentists towards or away from dental caries preventive measures¹⁶⁴ concluded that the evidence available “seemed to indicate that further education and training coupled with a fairer pay scheme would be a reasonable approach to change the balance in favour of the provision of dental caries preventive measures by dentists”. Other complications include suggestions that many UK dentists have very positive attitudes towards prevention and that younger and female dentists tend to engage more frequently in preventive activities¹⁶⁵. The debate on remuneration in India has highlighted the challenges in finding an ideal system for dentists working in primary and community health centres¹⁶⁶ and challenges in motivating dentists to provide patient-centred care whilst not distorting the payment system.

In many health systems there appears to be something of a two-tier system where the financial and other information required to consider the adoption of any new system is set at a level well above that currently available for the existing, outmoded systems.

Innovations in remuneration systems

There are numerous examples of debate and some innovations in the remuneration area; there is not space here for an exhaustive list. The Scandinavian countries have led the way by having a preventive strategy embedded in both their public and private systems for decades. In the UK, following reports outlining the problem of an outmoded treatment strategy for caries in the 1980s and 90s, attempts to change General Dental Services contracts (for “high street” Dentists) started with a landmark document from the National Health Service in 2003 called *Options for Change*¹⁶⁷. Sadly, these very progressive

proposals for contract reform to a more preventive style of dental care were mired in arguments about a mis-matched payment system added later. The debate began again following the independent *Steele Review*¹⁶⁸ in 2009, and pilots of a more preventive style of contract and remuneration have now been followed by “prototype” contracts and the implementation of a preventive series of guidelines called *Delivering Better Oral Health*¹⁶⁹.

In Germany there has been a move away from paying heavily for technical work and inclusion of specific payments for prevention and fissure sealants in General Dentistry. In the US there have been long discussions with stakeholders about the potential of more preventive dental insurance contracts (for example at the 2008 ADA meeting on Caries Classifications and the Temple University Workshop on Caries Management Pathways¹⁶). Very recently there have been some encouraging signs in the US with the addition of 11 new payment codes in the US CDT System¹⁷⁰ (Codes on Dental Procedures and Nomenclature), many of them with a diagnostic or preventive application. It is noteworthy that in many societies the public and professions are quite content to pay for medical or legal advice, but this is a foreign concept in Dentistry.

There follows below a brief “SWOT” analysis of a typical current caries remuneration system in order to illustrate the issues in this important and controversial field.

Paying for appropriate Prevention and Management in Caries Care – SWOT Analysis of the traditional model of remuneration:

Strengths

- Paying fees for specific items of restorative care is well understood by dentists, patients and third party payers.
- The system has been seen as technically efficient- but ONLY IF caries care is measured by the numbers of cavities cut or kilograms of amalgam or other restorative material used.
- The system is seen as being difficult to defraud, as there is evidence of each restoration placed (although the evidence of what was there before the restorations has typically been destroyed).

Weaknesses

- Typically, fees to compensate for the time spent by the Dentist (and Team if there is one) on: *Determining patient- level caries risk, Detecting caries stages and Assessing caries activity, Deciding on a personalized care plan, and Doing what many patients require to restore and maintain health in terms of providing both preventive advice and, where needed, non-operative care* – **are either not available, or are paid at an uneconomic level.**
- There is therefore an incentive for the dentist to provide income-generating restorative care where possible, but no balancing compensation to provide the remainder of what the profession has recognized for decades to be a more evidence based, modern approach that is in the patients’ best interests.
- The traditional System does NOT reward preservation of tooth tissue or the minimally invasive approach advocated by the FDI since 2002¹.
- The Traditional System is out of line with the ways in which Outcomes of care are assessed elsewhere in Healthcare and should be assessed in caries care (see *Section 13*).

Opportunities

- Building of the Scandinavian foundation, the increasing number of national examples of positive developments to devise and implement methods of “paying for prevention” should provide reassurance and encouragement for those who have not yet reformed their payment systems to do so.
- Medical Insurers with preventive plans in other arenas (such as cardiovascular health and diabetes) are increasingly looking at dental plans and asking why don’t these also pay for prevention to maintain health and reduce later disease burdens and costs.
- The increasing advent of evidence-based health-care is driving the public, patients and policy makers to look at this issue and advocate for prevention and protection of the patient’s long term oral health.

Threats

- The complacency of many parties satisfied with (and/or benefiting from) the status quo.
- The inertia of well-established health systems.
- Dental payments are often seen as “too complicated to change”.
- Vested interests can undermine efforts to update and change.
- Developing countries can be keen to follow developed countries into outmoded payment systems and treatment philosophies which they can ill afford.

Call to action:

All stakeholders in national or local contract specification and negotiations which includes caries care should ensure that: 1) remuneration is considered as an important element; 2) remuneration should incentivize preventive, evidence-based tooth preserving caries management and only support operative intervention when this can be shown to be needed; 3) the patient's best interests should stay as the paramount consideration in all such discussions and agreements.

Section 11 The role of the dental team and other health professionals (opportunities across different countries)

Introduction and international context

The dental team includes a wide range of oral health professionals with different education, training, skills and competencies, scopes of practice, licensing, recognition and supervision requirements, depending on national regulations, available resources and community needs.

Dentists are health professionals. They are responsible for diagnosis and for providing adequate care which respects quality and safety regulations. Furthermore, they lead the team, and therefore have a supervision and management role. Other healthcare professionals include dental nurses and chairside assistants, dental surgery assistants, dental hygienists, dental technicians, mid-level providers, dental therapists, clinical dental technicians, or denturists, community oral health workers. The names and scope of practice of all these professions are defined nationally and can differ from country to country⁶⁵.

The distribution of dentists and other oral healthcare workers is highly unequal, both among and within countries, as dentists for instance tend to concentrate on more urban and affluent countries/ areas. Because of a salient lack of detailed statistics, however, depicting a truthful picture of oral healthcare workforce availability is very challenging: to date, the Global Health Workforce Statistics assembled by WHO collate all oral healthcare workers into the single category of “dentistry personnel” without any distinction. As a result, it does not allow a compilation of a dentist: population ratio by country. As for data compiled by FDI, it is still a work in progress at this stage.

What can and should be achieved with caries prevention and teams right now

It is important to appreciate that the change in treatment philosophy (from restorative bias to preventive orientation) outlined in the earlier Sections require a change in the mindset of the dentist and that this change in clinical professional philosophy can (and should) happen right now. This is the case whether the dentist is a single handed practitioner or the leader of a team (where it is arguably even more important). Changing to a more preventive approach should not wait for any changes in team structures. However, if public and patients are going to benefit to an optimal extent from the shift to prevention, then the team opportunities should be examined very carefully within the local and national context.

To move towards a more prevention-oriented, multidisciplinary, team-based care, as presented throughout this White Paper as a means to improve the prevention and management of dental caries, dentists must open up to collaboration. As outlined in FDI's Vision2020 document, a new model of oral healthcare delivery can be shaped, which “relies on a team-based collaborative approach where fully trained dentists take responsibility for supervising a team, provide sufficient training to the healthcare workforce and delegate specific tasks ...while retaining full responsibility for diagnosis, treatment planning and treatment”⁸. This collaborative approach, both within the oral health profession, and externally in relation to other health professions, is a key determinant in successfully moving to a preventive approach to caries management and needs to be given a high priority by NDAs and in dental education.

The successful adoption of a teamwork approach depends on various drivers, including, but not limited to:

- What do national regulations foresee? Who is licensed to do what? With which level of supervision/independence?
- What do remuneration schemes foresee? Who is remunerated for doing what? Are management, coordination, supervisory tasks accounted for in remuneration schemes?
- What is the profile of the available workforce? Which kinds of (oral) healthcare workers are most fit to reach out to the community? To the individual patient? How easy is it to initiate collaborations with these workers?
- Is education and training of oral healthcare workers and of general healthcare workers shaped in such a way that it fosters collaborative practice?
- Are communication channels available to foster teamwork both within the dental team, and externally?
- Which kind of infrastructure is available? Where can community members be reached: in dental clinics, in community hospitals, in their own community, in schools, etc? And which healthcare workers have access to these settings?
- Cost-effectiveness: who provides which care at which costs?

The answer to these questions will differ from country to country, and there is no one answer. However, in order to allow for a paradigm shift from a restorative to a preventive approach to dental caries management, roles and responsibilities within the dental team and shared with other healthcare professionals must be openly discussed and proactive steps taken by oral health professionals to impact this change. So far, examples of collaborations in the field of caries prevention, and to a lesser extent management, are abundant. In some cases, they are the result of large scale, top-down initiatives. In many other cases, they are the result of local, bottom-up initiatives.

What can be achieved with caries prevention and teams in a more multi-disciplinary and inter-professional future

The recently published FDI document [“Optimal Oral Health through Inter-Professional Education and Collaborative Practice”](#)¹⁷¹ provides a more in-depth view of what collaborative practice entails, and presents several case studies of successful implementation schemes. Below we briefly outline a few examples from around the world to illustrate different ways to (re-)define roles and responsibilities of dental team members and externally of other healthcare professionals in a collaborative approach. Altogether, these examples reflect an evolving role for dentists, placing the profession in the role of project designers, councilors, supervisors, and managers rather than in the role of implementers only.

They are only selected examples and both design and implementation will differ depending on countries, settings, workforce availability and community needs.

Case studies

Redefining tasks, roles and responsibilities: In 2000, the Netherlands introduced a new system which reorients care delivery. In order to cope with changing disease patterns and an increased need for prevention, the Dutch government decided to adapt the structure of its oral health services. The reform emphasized the importance of structured collaboration between dentists and hygienists and focused on task reallocation. Under this new system, dentists, hygienists and dental assistants care for patients, not according to a hierarchical structure, but according to the need of the patient¹⁷¹.

Delivering interprofessional education: To date, interprofessional education is still the exception rather than the rule. Recent studies from North America show that less than 20% of dental schools from US and Canada deliver courses to interdisciplinary groups including not only future dentists, but also dental hygienists as well as medical and nursing students^{172,173}. Similarly,

education in medical and nursing schools still largely ignores oral health: in a study of 88 medical schools in the US, 69.3% reported offering less than five hours of oral health curriculum¹⁷⁴. The initiative recently launched by the New York University School of Nursing: Putting the Mouth back in the head: HEENT to HEENOT provides an example of interprofessional oral health workforce capacity building in order to improve access to oral health¹⁷⁵.

Involving the wider health community: In some countries, only few dentists are available, and remote areas are dramatically underserved. In such settings, delegation of tasks becomes essential. Further, considering the issue from a life-course perspective, different approaches might be relevant depending on who is to be reached: for instance, reaching out to young mothers in an antenatal clinic might necessitate the intervention of a midwife; reaching out to the elderly in nursing homes might call for the involvement of the institution's healthcare personnel etc.). Programmes such as FIT for School in the Philippines, or Child Smile in Scotland are good examples of how different members of the

wider healthcare team (e.g. nurses), and even of the wider community (e.g. teachers and educators) can contribute to caries prevention^{176–178}. As another illustration, various local projects where dentists around the world train members of the wider health community as well as lay people, have shown positive effects in terms of oral health behaviours¹⁷⁹.

Integrating oral health teams in primary care teams: In Brazil, the government decided by decree in 2000 to include oral health teams into its Family Health Strategy. As a result of this team-based, interprofessional approach, access to oral healthcare increased from 15.2% to 53.2% of the Brazilian population in just 7 years (2002-2009)^{180,181}.

Delegating to provide cost-effective care: New Zealand, followed by approximately 50 other countries, has set up a model in which dental therapists practice in schools in order to deliver adequate care to all school children. Numerous studies show that the care provided in schools by these dental therapists is of good quality, improves access to care and is cost-effective¹⁸².

Section 12 Supporting change in caries management where it's needed

This Section builds on all of those coming before it which, taken together, indicate that for many but not all dentists, **there needs to be some change in what they do in their daily practice for the clinical management of dental caries**. The magnitude of these changes will vary, from minor modifications or updates to clinical protocols or practice procedures or interactions with patients on the one hand, to fairly fundamental shifts in the philosophy of clinical caries management on the other. Support will be needed for both ends of this change spectrum and the type of support provided will need to be tailored to the need of the dentist, dental team or the other healthcare professionals who can also become involved in caries prevention and management. In order to prevent and manage caries effectively for both individual patients and wider communities, dentists will also have to be aware of, work with, and advocate for parallel activities outside of the dental office. This too may need a change of approach for some, which in turn needs to be supported.

Health professionals are obliged to keep up to date and to incorporate new evidence into their practice for the benefit of their patients. However, it is unrealistic to expect such shifts in practice without support. This may vary from creating new resources for life-long learning and Continuing Professional Development, to the production of new paper or software tools and explanations of how best to practice in this “new” way, to the provision of some incentives to change. These can be both from a clinical/professional point of view (“why I need to change, how to do it”) as well as from an economic, business development (“keeping my practice economically viable”) perspective.

There also are a range of geographic scales to the support needed which can be framed locally, nationally and globally. Local may be at the individual dentist level or working with small regional/state groupings of dentists, *National* may be appropriate when the country-wide scale benefits the production and distribution of nationally relevant, practical, evidence based and agreed guidelines for example, while *Global* is

also useful, for example at FDI level, where there are visible global trends and needs as to the direction that dentistry and health-care need to move in⁸. The Caries Prevention Partnership is an example where a range of tools (this White Paper, the Advocacy Toolkit and Education webinars) can help NDAs and dentists make the changes they decide that they need to make in the area of caries prevention and management.

Barriers to change

There are many barriers to change in health care and dentistry is no exception. In healthcare it has been said that it can typically take 15 years for a proven intervention to be adopted in clinical practice and systematic study of this area has developed as the field of “Implementation Science”^{183,184}. In this context dentistry overall has been very conservative and has resisted change in many areas (such as in caries classification (Section 3) and in secondary prevention (Section 7), but not in others (such as in the more rapid adoption of Implants or intra-oral cameras). Dental caries care has been seen as such a basic part of dentistry that it has been a largely ignored area, as other innovations have come and gone.

More attention is now being turned to understanding change in caries practice and the barriers and facilitators that underpin and influence it, including the influence of education as well as financial incentives, which have been compared (for fissure sealants) in a formal randomized clinical trial setting¹⁸⁵. There are also cross linkages here to the discussions found elsewhere in this White Paper on remuneration (Section 10), the dental team (Section 11) and outcomes (Section 13).

At the level of supporting change for individual dental procedures, a recent editorial looking at the lack of change in the management of deep caries and the related terminology has provided a useful summary of some of the attitudes encountered¹⁸⁶. The authors refer to the terms that some dentists use in that they either “Don’t Know, Can’t Do, or

Won't Change" and suggest that these are the key barriers to moving knowledge to action in managing the carious lesion. Although this group fail to consider some of the other work in the area, they usefully point out that just producing new evidence, however compelling, is not enough to immediately produce a significant change in clinical practice. There has been and should be a focus on reducing the "Don't Know" element as the first step in closing the so called evidence gap. Seeking to secure the production of high quality, evidence-based guidelines and to disseminate them effectively is also important. However, there is growing recognition that these steps alone will not defeat the Can't Do and Won't Change barriers, which are both complex and multi-faceted.

The range of tools which would help to support change include:

- Educational developments (signposting existing resources, adapting - not duplicating them, then identifying and producing any needed new resources in accessible, flexible electronic formats).
- Implementation activities utilizing a broad range of options from the blindingly simple and inexpensive (appropriate paper charts, checklist) to the far more complicated but potentially game-changing (full-blown integrated IT systems that automated data collection and decision support).
- The ICCMS™ System outlined as an example in Section 9 has, in addition to the "Guide for Practitioners and Educators", a range of implementation tools being produced for it including:
 - A new shorter, simpler (4D) Quick Reference Guide
 - Updated e-Learning software across the Domains of Practice, Education, Public Health and Research
 - Tablet-based iCaries Care software for patients
 - Paper-based iCaries Care explanation sheets for patients

Tablet-based software for epidemiology

- Exploratory links into practice software systems

The *Global Collaboratory for Caries Management* (GCCM) set up under the ICDAS Foundation (www.ICDAS.org) is bridging a wide range of groups who are working together on implementation of the ICCMS™ System across Countries seeking to achieve incremental improvements of this caries management system, as recommended by the FDI Policy statement in 2012³.

- Specific technology developments of both devices and more preventive treatments that help preserve dental tissues - in order to support dentists' optimal assessment, re-assessment and minimally invasive clinical care of caries. Examples include technology to support more effective and efficient:
 - Caries risk assessment
 - Detection and recording of the stages of caries and changes over time
 - Assessment of lesion activity.

(Although progress with such devices for routine use in dental practice has been frustratingly slow, this remains a priority area).

At the level of support for joining up ALL the elements required from both inside and outside of dentistry in order to make a real difference in caries prevention and management, we also need a broader view of supporting the integration of pieces of the caries puzzle that do not typically align without help. Figure 13 is derived from an International Symposium on Dental Caries held in February 2016 at the UAE International Dental Conference in Dubai (AEEDC) by the Alliance for a Cavity Free Future and King's College London¹⁸⁷. Individual experts from each of the fields identified in the Puzzle-pieces reviewed not only what needed to be done in their area, but how the elements could and should work together synergistically for optimal caries control in both patients and populations. All agreed that to make significant progress to improve the current situation the pieces have to be made to fit together in locally appropriate ways. Putting all

the emphasis on one or two pieces alone will not support meaningful change. The broad range of participants stressed the need to support working across the puzzle “pieces” to best operationalize the existing evidence.

Within dentistry: we need to align the key “disciplines” including: nutrition, education and behaviour change, cariology, (dental) public health, clinical practitioners and those developing practice-friendly versions of caries management systems (such as “4D” ICCMS™, Section 8).

Outside dentistry: as an excellent editorial in the Lancet pointed out back in 2009 that “Prevention is key” and “Good oral health should be everybody’s business”¹⁸⁸; therefore, we also need to join up the pieces to link with suitable actions from other external stakeholders – including other health professions (such a physicians and nurses), wider public health groups, the public, the patients and other stakeholders.

This more “joined up” approach will allow dentistry working with the wider health professions and others, to together support colleagues and patients to achieve optimal caries prevention and management more rapidly than working only in

Figure 13 – The Caries Prevention and Management Puzzle

‘Joining up’ the evidence to make an achievable difference in Caries Prevention and Management
[From the AEEEDC Dubai Symposium, 2016]



some parts of caries puzzle. Ways of achieving such integration and support have to be scripted and adapted locally at the practice, patient, system and country levels with appropriate, localized, language and communication tools for each. This may require a range of different initiatives and partnerships, all of which should be designed to be sustainable if continuing improvements are to be maintained.

Call to action:

Dentists should be well supported where they need to be in: 1) moving towards an up-to-date, comprehensive, evidence-based, risk informed, tooth preserving, preventive caries management system; and 2) in working effectively with a wider range of internal and external partners to help control caries at both the individual patient and wider community level.

Section 13 Caries prevention and management: assessing outcomes/progress

Introduction

Comprehensive patient care plans should, by design, focus on achieving good health outcomes for patients. It is also implicit that health promotion outcomes are desired and that this is an important aspect when considered at both the patient and community levels. The outcomes should be value-focused and not value-blind. In addition to the four types of outcome shown in Figure 13, locally relevant outcome measures should also be developed and added, as appropriate. Measures should be sensitive to change over time and tooth-surface level information is therefore desirable.

The use of comprehensive, risk-based preventive caries management systems that focus on maintaining health and preserving tooth structure should facilitate feedback on the success of care to patients and dental team as well as informing the on-going reassessment and review of caries care. Outcomes data and the recorded systematic use of a system like ICCMS™ may also help dentists in many countries demonstrate “quality” and protect them in terms of legal liability and challenge with regard to caries management. Outcome information can also be used in research, evaluation and improvement of caries management systems. The analysis of the outcomes will also facilitate feedback to patients and to third-party payers.

Outcome data at the local, national and global levels

The use of outcome data should also be thought of and planned at three geographical levels: local, national and global. Such data is now a priority internationally for governments, insurers, health services and public health groups and also patients’ groups and economists. Unfortunately, in oral health, such measures are quite poorly developed at this stage. The advice from most quarters is to start simple and build-up in terms of the number and complexity of measures. As technology advances and the use of BIG Data becomes more routine, we can expect

more and more useful outcome data to become available as a by-product of the use of routine IT Systems, if such systems are configured properly and agreements are in place between patients, dentists and payers (who ultimately will all benefit).

The challenge we face at the moment includes the complexities of and fragmented nature of the dental IT infrastructure in many countries and a software industry which is unsure how to proceed in the absence of consensus as to what is required. There is an opportunity for aligned simple specifications to be assembled by NDAs with customizable elements built on an agreed core. There is also a role for FDI, once again the most recent policy document in this area³ recommends “that adequate and appropriate surveillance, record keeping and IT support systems be developed for preventive and minimally interventive caries management”.

The outcomes of using comprehensive preventive caries management systems can be grouped from four key aspects, which are shown in Figure 14 and summarized here:

1. **Health maintenance** – Outcomes may include:
 - Patients capable of **maintaining oral health and well being**
 - Number of truly sound teeth/surfaces maintained as **sound**
 - Number of restored teeth/surfaces maintained **free of new disease**
 - Initial inactive caries lesions **maintained unchanged**
 - Cyclic risk-based care & review to **establish and maintain long-term oral health**
2. **Disease control** – Outcomes may include:
 - Number of initial caries lesions that remain **unchanged or reversed**
 - Initial/Moderate/Extensive active lesions **managed effectively** (by either non-operative

or tooth preserving operative care, as appropriate)

- For both clinically and radiographically detected lesions **progression controlled**
- Tooth structure **preserved**

(Note that traditional D₃MFT is only in this one category)

3. Patient-centred quality – Outcomes may include:

- **Patients' satisfaction** with dental health status
- Improvement of patients' **attendance and care pattern being based on risk status**
- **Reduction or stabilization** of patients' caries risk status
- **Improvement** in oral hygiene and dietary practices

4. Wider impacts of using a caries management system such as ICCMS™ – Outcomes may include:

- **Changes** in care philosophy in: dental practice, dental schools, insurance systems, health

systems, national policies

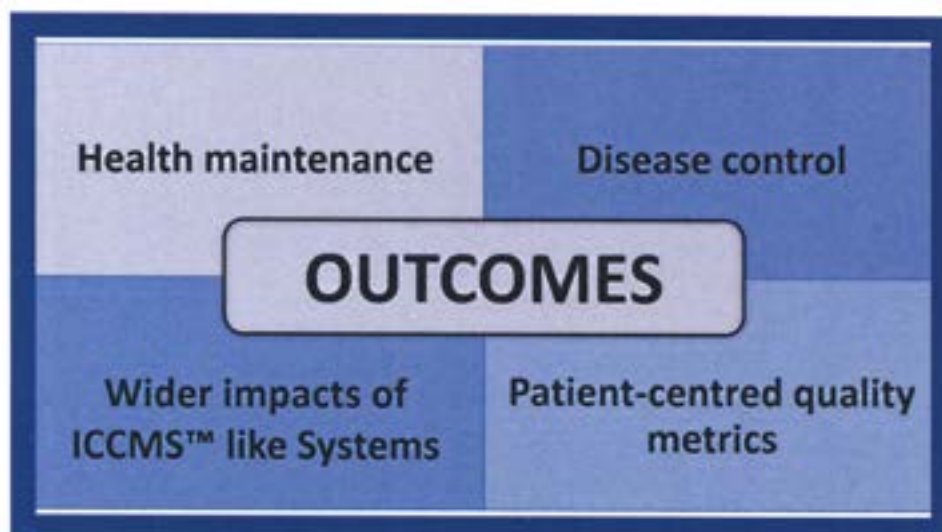
- **Research:** global collaborative studies
- Link to **general health goals** from WHO
- Facilitate **more appropriate reimbursement** systems
- **Improved value** for overall caries care

It is worth contrasting the approach advocated above with the traditional caries outcome, assessed if at all using only the basic method of recording a threshold of dentinal cavitation with the DMFT Index. This measure captures only one element of **disease control** as an estimate (without radiographs) of holes that need to be filled. DMFT has for decades been used by some at a range of different thresholds (see Section 3), while the perception in many countries is that it could only be used at cavitation level. By collecting DMFT data if still required (for historical comparisons with previous country data, for example surveillance data) with criteria including initial lesions, it is still perfectly possible to keep track of more advanced lesions and to compute directly comparable results to those produced previously at the cavitation-only threshold.

Call for action

Going forward it is important that: 1) the four types of caries outcome measures outlined continue to be developed and refined in ways that are appropriate locally, nationally and globally; and 2) that the IT support required to capture this information as efficiently as possible is developed locally, nationally and globally in parallel.

Figure 14 – Four key aspects of caries prevention and management outcomes (example from ICCMS™)



Section 14 A call for action

The challenges in 2016

In the field of dental caries there is an excessive **implementation gap** between the extensive research evidence we have accumulated over decades and its adoption in routine clinical practice. In many countries this has specifically been seen since the previous FDI Policy Statements in this area, published in 2002 and in 2012. There is an urgent need to shorten this implementation gap at the present time and to introduce mechanisms to ensure that, as new beneficial research findings are made available, they can then be evaluated appropriately in a predictable and efficient way so that they can be used to update daily practice and improve caries control.

As dental caries (tooth decay) continues to represent a significant burden across the life-course on a global level, the dental profession, in order to fulfil its professional obligations, seeks to re-prioritise the interests of both patients and the public by significantly modernizing and improving the prevention and management of dental caries.

This should be done by being inclusive and collaborative, both within the various aspects of dentistry (which can often be deeply “silo-ed”) as well as with external partners in health (from nurses to physicians) and healthcare. The tendency for research to be repeated, or rejected as it is “not invented here”, or simply “re-labelled” in attempts to create new niches should be minimized. Whilst maintaining clinical and academic “freedom”, wherever possible, building on international best evidence incrementally, should be the best way to improve patient health and healthcare.

Many groups and organizations within Dentistry have been asking for a move forwards towards more effective caries prevention and the preservation of sound tooth structure for more than 20 years – how do we now make it happen and happen more quickly? The message is not new, but to achieve the desired change it is now necessary to identify and overcome a range of barriers/factors in areas such as those associated with:

- Confusion over caries terminology, classification and treatment philosophies for both non-operative and tooth-preserving operative caries care.
- Excessive variation in the degree of investment in the methodologies employed and the quality standards used in caries epidemiology, as well as confusion in the interpretation of results by different stakeholder groups. We need high quality data which also can break out results for both initial-stage and more advanced stages of disease.
- Lack of tools (risk assessment tools, caries detection tools, caries activity assessment tools) and lack of a systematic approach that can work in daily practice.
- Education and knowledge transfer/ implementation for the wealth of evidence that is available in the field and specifically about: early disease, the caries process, the balance between demineralisation and remineralisation and links with risk assessment and clinical management.
- Lack of systematic communication across the domains of Education, Research, Practice and Public Health.
- Remuneration being provided for only some aspects of what is deemed internationally as appropriate caries care and the continuation of inappropriate (or outdated) financial incentives in Practice.

Further, creative solutions need to be shaped to meet a range of identified needs; specifically, the:

- Need for more effective primary and secondary caries prevention strategies across a range of caries risk profiles.
- Need, in particular, for the implementation of the 2015 WHO Guideline on sugars intake for adults and children to be clear and effective.
- Need to understand outcomes of caries and caries care better. Further development

is needed in robust measures for health maintenance, disease control, patient-centred measures of quality as well as wider impacts of systematic caries control.

- Need for less technique-sensitive operative materials with more tooth preservation and better longevity.
- Need to be able to provide IT support to capture this information efficiently locally, nationally and globally.

Call to action – key points

In order to meet the challenges outlined above, we call on national dental associations to consider the following priorities when setting up their own caries prevention and management recommendations, strategies, work plans, and advocacy activities. The actions listed below cover many different fields. Some can be implemented by the dental profession itself, some pertain to education and can be discussed with dental schools, deans etc. and others relate to policy and need to be brought to the attention of health authorities. Yet dental community leaders have a role to play in driving each of these actions forward.

Prevention

Support for caries prevention efforts at both the individual and population levels:

- Primary prevention covers a very large spectrum and needs to target different audiences: 1) individuals (oral health literacy, oral hygiene, diet); 2) dental practitioners (use of fluorides, diet advice, dental sealants...); and 3) policy makers (policies re. fluoride, re. availability of sugary food and drinks etc...). Primary prevention is a key element of state-of-the-art caries prevention and targeted strategies are needed to address each different stakeholder group. Further, there are opportunities arising from the common risk factor approach to link caries prevention with hygiene and the control of obesity and diabetes.
- Secondary prevention: the prompt and efficacious application of preventive care to a specific lesion, once it has been detected and assessed, provides a very significant opportunity

to stop lesions from ever progressing to the stage at which surgical intervention is required and to preserve tooth tissue. This aspect of caries care should be a priority and fully integrated into routine dental practice for all age groups.

- All prevention strategies should be integrated both across the dental domains and team and wider, outside of dentistry in order to reach all age groups and help control other diseases which share common risk factors. This is key to achieving the re-integration of oral health into general health.

Clinical practice

Initiate a shift in the management of caries:

- A shift in caries management to detecting caries at an early (non-cavitated) stage and adequate risk assessment to determine appropriate preventive intervention and recall frequency needs to be supported.
- Dentists should be well supported where they need to be in: 1) moving towards an up-to-date, comprehensive, evidence-based, risk-informed, tooth preserving, preventive caries management; and 2) in working effectively with a wider range of internal and external partners to help control caries at both the individual patient and wider community level.
- It has been appreciated for some years that technology developments in the areas of both lesion detection and activity assessment as well as risk assessment are urgently needed to help dentists, the dental team and patients. Although progress with devices, software and techniques to use in dental practice has been frustratingly slow, this remains a priority area in order to support dentists' optimal assessment, re-assessment and minimally invasive clinical care.

Education

Promote a redefinition of cariology curricula

- There is a fundamental need to get cariology education and training re-launched in an effective and efficient way. Education must be

up-to-date and evidence-based and must be delivered at both the undergraduate education and continuing education levels.

Integration

Work towards a stronger integration within oral health and into general health and health policy.

- Oral health should be seen as part of General health; dental teams can help with detection and prevention of systemic conditions whilst more generalist health professions have an important role to play in caries prevention.
- Caries prevention and control strategies need to be put in context with the implementation of the UNEP Minamata Convention (phase-down of amalgam, phase up of prevention).
- ***Within dentistry:*** we need to align the key “disciplines” including: nutrition, education and behaviour change, cariology, (dental) public health, clinical practitioners and those developing practice-friendly versions of caries management systems (Section 8).
- ***Outside dentistry:*** the dental profession should advocate that “Prevention is key” and “Good oral health should be everybody’s business” and seek to join up the pieces to link with suitable actions from other external stakeholders – including other health professions (such as physicians and nurses), wider public health groups, the public, the patients and other stakeholders.

Financing

Participate in re-thinking remuneration mechanisms for caries prevention and management.

- All stakeholders in national or local contract specification and negotiations which includes caries care should ensure that: 1) remuneration is considered as an important element; 2)

remuneration should incentivise preventive, evidence-based tooth preserving caries management and only support operative intervention when this can be shown to be needed; and 3) the patient’s best interests should stay as the paramount consideration in all such discussions and agreements.

- Health Systems need to avoid investing in heavy and costly infrastructure that might be unnecessary.

Evaluation and Data

Encourage data-driven, evidence-based caries prevention and management.

- The quality of data collected needs to be improved in order to obtain data which is appropriate, valid and comparable (across regions, countries, but also over time). In addition, disease detection thresholds must be placed so that prevention needs and success can be assessed and monitored.
- These should typically go beyond the simple “No obvious decay” or “obvious decay” call at the cavitated caries into dentine D₃ threshold to either a level which corresponds to the D₁ threshold including enamel caries with a limited number of stages of caries severity, or a more comprehensive staging of caries severity across the caries continuum (see Section 3).
- Going forward it is important that: 1) the four types of caries outcome measures (health maintenance, disease control, patient-centred quality and wider impacts of using a caries management system) continue to be developed and refined in ways that are appropriate locally, nationally and globally; and 2) that the IT support required to capture this information as efficiently as possible is developed locally, nationally and globally in parallel.

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